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SPECIAL FEATURE: ORIGINAL ARTICLE

Promises of Bioeconomic Change as a Strategy for Avoiding Socio-ecological Transformation

The making of sustainability: ideological strategies, the materiality of nature, and biomass use in the bioeconomy

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Abstract

The bioeconomy, a recent addition to the political project of ecological modernization, is largely premised on the widespread use of biomass. Biomass is presented by bioeconomy proponents as renewable and, therefore, sustainable. However, a large body of academic and non-academic literature questions this sustainability, citing the negative socio-ecological aspects of biomass use. Given this contradiction, we ask how the key institutions of the innovation system (government, science, and industry), construct and uphold the image of sustainability of biomass use in the bioeconomy. Through an analysis based on ideology critique, we look at the broad field of biomass policy in Germany, including official bioeconomy strategies and biomass potential calculations, expert portrayals of biomass use in the bioeconomy-themed Year of Science, and an iconic biomass-based commodity. We identify four central ideological strategies that uphold the image of sustainability and contribute to creating political consent for the political project of the German bioeconomy: seeking managerial solutions, relying on technological innovation, relegating solutions into the future, and obscuring the materiality of nature. We discuss how these strategies are upheld by the wider discourse and institutions of ecological modernization and argue that particular attention should be given to the biophysical materiality of living nature in this context. The materiality of nature represents both an obstacle to the ideological strategies identified, and a starting point for envisioning alternative society–nature relations.

Keywords Biomass · Bioeconomy · Sustainability · Materiality of nature · Ideology critique

Introduction

The bioeconomy is one of the central contemporary political projects that promise to make societies more sustainable. As an increasingly important paradigm permeating our understanding of nature–society relations[1] at the international level and shaping national political, economic, and social agendas, the bioeconomy is considered by some scholars as one component of the wider political project known as ecological modernization (Baasch 2021; Backhouse et al. 2021). Ecological modernization is characterized by an understanding of ecological problems as specific and isolated from one another. As an approach to addressing the environmental crisis, it tends to be technology-focused, based on the use of discrete problem-solving tools to achieve change through small, incremental steps. The underlying assumption is that ecological problems and economic growth are not contradictory (Hajer 1995; Krüger 2013, 2015).

A key feature of bioeconomy projects around the world (currently, 60 countries have developed bioeconomy

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[1] "Society–nature relations" is our translation of the German term, *gesellschaftliche Naturverhältnisse* (Brand and Görg 2022). In this understanding, nature and society are distinguishable, differentiated poles of a dynamic process of mediation (ibid, citing Jahn and Wehling 1998). The term acknowledges that many dimensions of nature are mediated by society, including not only the biophysical modification of nature, but also culturally mediated understandings of nature. At the same time, nature is understood as prior to and a prerequisite for societal activities and societal relations, denoting biophysical processes that can be modified by society, but which are not wholly under its control (ibid.).

strategies) is the focus on biomass as a new material basis of the economy. Increased use of biomass to partially substitute fossil resources is complemented by the adoption of new technologies to increase its energetic efficiency (Sillanpää and Ncibi 2017). Biomass also plays a key discursive role in the bioeconomy, denoting a material that is 'renewable' and, therefore, 'sustainable', thereby legitimizing the bioeconomy transition as a response to the climate crisis (Pfau et al. 2014; Priefer et al. 2017). However, many observers have questioned claims that a sustainable increase of biomass use within the bioeconomy is feasible, especially in the global North where most countries are already net importers of biomass (for an overview see Allain et al. 2022). They point to significant risks associated with increased biomass imports, including biodiversity loss and reduced food security, particularly in the global South (Mills 2015; Sinaga 2021; Toledo López 2021), and cast doubt on the feasibility of substituting bio-based inputs for fossil fuels as a means of decoupling economic growth from carbon emissions (e.g., Giampietro 2019). In Germany, a driving force of bioeconomy policies, criticism of the idea of a sustainable increase of biomass use has become widespread. In 2012, the German National Academy of Sciences noted the limited capacity for biomass substitution from German sources or from abroad (Nationale Akademie der Wissenschaften Leopoldina 2012, p. 7). Germany is already a net importer of biomass (Bringezu et al. 2020)[2] and studies have shown that Germany has very limited potential to produce additional biomass from residues and waste. The German Biomass Research Center (DBFZ) estimates potential production of useable biomass to be 85.6–139.6 million tonnes (Mt) per year, of which 66–84% is already in use (Brosowski et al. 2019, pp. 14–17) and other studies question the feasibility of increasing global biomass production and use at all (Haberl et al. 2005; Krausmann et al. 2008). Furthermore, there are currently no agreed operationalizable criteria for assessing ecological, ethical, or social sustainability within the wider fields of bioeconomy policy and research (Schweinle et al. 2020, p. 4).

Despite the uncertainties and contradictions regarding the conditions that would make large-scale biomass use sustainable, the dominant policy discourse continues to create an image that portrays the large-scale substitution of fossil and mineral resources by biomass-based materials as a feasible goal that will facilitate the transition to a sustainable society: "With the expansion of the bioeconomy, the resource base of the economy is aligned towards sustainability and fossil raw materials are replaced" (BMBF and BMEL 2020, p. 10). Beyond Germany, the bioeconomy also continues to grow in popularity (Allain et al. 2022) and the dominant discourse of its proponents upholds the image that sustainable biomass use is possible (Vivien et al. 2019). For example, the EU's Bioeconomy Strategy relies heavily on the notion that an increase in biomass use will lead to more ecological sustainability: "Remaining under the 2 °C limit will not be possible without sustainable bioeconomy activities, given their potential for carbon sequestration, [and] the substitution of fossil resources with sustainable biomass-based resources […]" (European Commission 2018). Thus, within the bioeconomy project, widespread criticism regarding the possibility of sustainably increasing the use of biomass is at odds with policy strategies and papers maintaining that biomass use is sustainable.

We argue that proponents of the bioeconomy use distinct ideological strategies to uphold the image of an increase in biomass use as a sustainable option for future economies and thereby contribute to creating political consent for the bioeconomy. We analyze these strategies by looking at the German case. Germany was one of the first countries to adopt bioeconomy policies and, as the driving force behind three Global Bioeconomy Summits, has been one of the key promoters of a bioeconomy transition worldwide. We ask how policy discourses in Germany sustain the image of sustainable biomass use, and how this contributes to creating political consent for the bioeconomy as part of the wider political project of ecological modernization. Following Gramsci's political theory, our guiding assumption is that this image of sustainability is upheld by particular ideological strategies that build upon and restructure formally structured and 'common sense' understandings of sustainable biomass use and that these ideological strategies are important for how political consent is created. We argue that these strategies are a key component of the current ecological modernization project, which differs from earlier versions of ecological modernization in that the biophysical materiality of living nature is at the center of its productive and discursive bases.

Our analysis builds on studies in the field of environmental policy analysis that shed light on the interpretive and ideational dimensions of meaning-making in public environmental policy (Wagenaar 2014; Fischer et al. 2015). Hajer (1995) shows how discursive strategies are used to establish ecological modernization as a major political project that aims to reconcile economic growth and ecological sustainability. Other scholars adopt a similar approach to analyze the discursive mechanisms employed in the development of a range of environmental policy initiatives (for an overview see Leipold et al. 2019). Our study contributes to a relatively new debate on the discursive dimension of the bioeconomy that has so far received little attention (ibid.), building on a handful of recent studies that identify different bioeconomy

[2] Currently, Germany extracts a total of 330 million tons of biomass per year and imports additional 145 million tons, of which 17 million tones are exported (Bringezu et al. 2020, p. 78 graph 5.1; p. 85 graph 5.4).

narratives. While all bioeconomy projects entail the use of biomass, narratives may focus on biotechnology, biomass, or the concept of degrowth and sufficiency (Bugge et al. 2016; Hausknost et al. 2017; Vivien et al. 2019). Each narrative incorporates distinct visions of sustainability, governance, future economic development, technological trajectories, and imaginaries of nature (Vivien et al. 2019). The dominant narratives focus on biotechnology and biomass, and the concepts of substitution and green growth, while visions based around agroecology or self-sufficiency remain marginalized (Hausknost et al. 2017; Vivien et al. 2019; Dieken and Venghaus 2020). Vivien et al. (2019) point out that the term 'bioeconomy' has lost its original radical meaning and is now used to reconcile economic and environmental goals in similar fashion to the term 'sustainable development'. Overall, this work shows that the bioeconomy is a *contested political project*, incorporating competing visions of how nature–society relations are to be organized, e.g., with regard to what technologies are implemented, what notions of sustainability prevail, and what role growth and the further valorization of nature play therein. Existing studies (Goven and Pavone 2015; Lühmann 2020; Backhouse et al. 2021) acknowledge criticisms regarding the feasibility of sustainable large-scale use of biomass and highlight contradictions in the dominant biotechnology and biomass-centered discourses. However, this literature does not show how bioeconomy proponents construct the use of biomass as sustainable in a way that is coherent and plausible, despite the forceful criticism they face.

The next section describes our analytical framework and the methodology employed, including data sampling. This is followed by a presentation of the results, where we identify four ideological strategies. The final section discusses the strategies in the context of the wider transformation of contemporary society–nature relations.

Analytical framework and methods

Our research approach is informed by critical theories of ideology which analyze the role of contradictory worldviews or meanings in creating and reproducing dominant power relations by making particular worldviews appear coherent, appealing or universal (Haug 1993; Koivisto and Pietilä 1996; for overviews see Rehmann 2013). In the context of our paper, this approach helps interpret how the creation of specific ideological strategies makes large-scale biomass use appear sustainable, despite the fact that full calculations are unavailable, and that those that exist are cautious about the feasibility of sustainably deploying biomass as the material basis for the German bioeconomy.

We adopt the theoretical perspective on ideology developed by Antonio Gramsci (Gramsci 2012a, b). The Gramscian approach differs from post-structural discourse analysis approaches in which the political and institutional contexts play a subordinate role in the creation of ideological features of society. The Gramscian notion of ideology shares similarities with the concept of 'sociotechnical imaginaries' in Science and Technology Studies, defined as "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects" (Jasanoff and Kim 2009, p. 120). However, in contrast to imaginaries, which are conceived "[…] as an important cultural resource that enables new forms of life by projecting positive goals and seeking to attain them" (ibid.: 122), critical theories of ideology analyze the creation of worldviews and meanings primarily vis-à-vis a political project, i.e., a project that seeks to prevail by achieving hegemony, understood by Gramsci as a consent-based political leadership that is actively created. In our case, this means contextualizing discourses on the sustainability of biomass use as part of the active creation of consent for ecological modernization, understood as a political project to make dominant particular ways of organizing society–nature relations, as described above. Accordingly, we assume that this political project and the ways that meaning relating to the sustainability of biomass use are deployed are the product of *ideological strategies* that are both contested and contestable. Such strategies are not monolithic, nor are they likely to be specific to the discourses of bioeconomy. Although the relationship of ideological strategies to a political project is a functional one, this does not necessarily imply an instrumental relationship in which ideological strategies are purposefully created. Rather, the ideological strategies we identify emerge from complex and not necessarily intentional social relations.

To identify these ideological strategies, our analysis of biomass discourse in context of the German bioeconomy distinguishes between two systems of meaning. On one hand, there are the structured meaning frameworks that we might expect to find in scientific definitions, biomass calculations and policy analysis; in Gramsci's analysis, these appear in realms such as science or philosophy, as an "intellectual order" (Gramsci 2012a, p. 1377, c, p. 1056). Such structured frameworks typically follow a rational and coherent logic and the ideas of a particular individual or an intellectual group (Gramsci 2012a, p. 1381). In the context of the German bioeconomy, the importance of this type of formally structured knowledge is underlined by the fact that the project was initially termed as the 'Knowledge-Based Bioeconomy'. Here, the term 'knowledge' referred especially to formal and systematic knowledge associated with a wide array of (bio-)technological innovations, calculations and models (Birch et al. 2010; Toledo López 2021). The second meaning framework comprises less structured, 'common sense' meanings, defined by Gramsci as a contradictory

and unsystematic discursive terrain of "divergent, incoherent, inconsequential" ideas and values, both conscious and unconscious, that a particular worldview hinges on (Gramsci 2012a, p. 1393). Despite the fact that biomass policy is largely structured around formal knowledge frameworks based on calculations, expert knowledge, and research results, we also expected to find common sense understandings across all documents we analyzed, since scientific, scholarly and other structured frameworks for understanding the world are not free of such suppositions (Gramsci 2012a, p. 1375). Thus, common sense ideas may be found in the context of formal scientific frameworks, including in statements made by scientists or politicians when addressing the wider public, as well as in their unreflected assumptions about the role of scientific research in the wider societal context. This follows Gramsci's understanding of common sense as including elements not only of past ideas, i.e., handed-down beliefs and understandings of the world, but also of "the most modern and progressive science" (Gramsci 2012a, p. 1376). For ideological strategies to 'work'—in our context, to create an image of sustainable biomass use for the bioeconomy—we assume that both formally structured and common sense understandings are reworked and contextualized, so as to appear plausible and appeal to particular social groups to create consent, i.e., active, "conscious and clear adoption" (Gramsci 2012b, p. 1671) of a collective will to move in a given political direction. When political consent is accomplished, Gramsci speaks of a 'historical block', a concrete historical constellation of forces related to a political project whose goal is the preservation of ideological unity through consent (Bollinger 2001).

To work with these theoretical assumptions, we identify both formally structured and common sense understandings in a range of documents that represent the communication of key institutions of the innovation system that is shaping bioeconomy policy in Germany: government, science and industry (see Appendix A for a detailed list):

(A1) Government positions are most clearly articulated in the most recent German Bioeconomy Strategies and related policy documents (2010 to 2020) that are referenced in these strategies, including the High-Tech Strategy and Agricultural Strategy. A total of six documents (378 pages) were reviewed.

(A2) Science positions are most clearly articulated in the three-tiered German Bioeconomy monitoring process commissioned by the Ministry of Agriculture, the Ministry of Education and Research, the Ministry of Economic Affairs and Energy and associated research institutions to assess biomass availability and sustainability from 2016 to 2021, consisting of 21 documents (952 pages).

(B) Both science and industry communication can be found in a total of 72 public statements made by natural and social scientists and business leaders considered to be experts in the bioeconomy. The statements address a wider public and were published online by the Ministry of Education and Research under the title 'Leaders of Change' ('Köpfe des Wandels') as part of the Year of Science 2020 between January and November 2020.

(C) Finally, we analyzed product information communicated by industry leaders relating to a biomass-based consumer commodity developed since 2014 with the support of the German government and hailed by research institutions as exemplifying the potential of biomass use in the bioeconomy: car and bicycle tires made of dandelion rubber as a substitute for petrochemical and/or tree-based rubber. Material released by the tire manufacturer Continental was supplemented by an interview with a research and development expert working in the field.

We chose these documents because they are representative of the discourses of the most powerful institutional actors in the innovation system in Germany's bioeconomy project, i.e., the ministries in charge of its implementation, business leaders, and academic experts. The selection of materials allows analysis of both expert-led policy-oriented discourse, and information presenting the bioeconomy to a wider audience of interested citizens, journalists, and civil society organizations (through the 'Leaders of Change' documents and publicity material about dandelion-based biomass).

For our analysis, we first considered the two main categories derived from our theoretical framework: formally structured and common sense understandings of biomass sustainability. We defined formally structured understandings of sustainability as those based on systems of knowledge such as biomass calculations and their methodologies; technologies to access and process biomass; models or targets for projecting biomass production and consumption; or plant breeding techniques to increase biomass output. We defined common sense understandings of sustainability as those characterized by unsystematic, spontaneous logic such as the assertion that 'since biomass from trees is a renewable resource, therefore, harvesting more trees is always sustainable'. We used qualitative content analysis (Kuckartz 2018) to develop an inductive coding system identifying the formally structured knowledge systems and common sense notions that are used to construct ideological strategies. We applied an initial set of codes to 20 percent of each of the four sets of documents in a common MAXQDA project. We then merged similar codes and filtered out less relevant ones, creating a list of the most important codes across all four sets of materials. Finally, we applied these new codes to all the documents. This analysis revealed that many of the inductively derived codes referred to common sense notions as well as formally structured knowledge systems, which suggests that the two are strongly intertwined, together creating and stabilizing the ideological strategies that uphold

the image of sustainable biomass use in the bioeconomy. Key inductive codes in our system included references to the role of biomass in creating sustainable economies; the positive or negative relationship between growth and sustainability; the role of technologies in creating sustainable biomass; strategies for achieving sustainable biomass use (through self-sufficiency or reduced resource use); the role of biomass in sustainable production and consumption; and societal aspects of sustainability (participation and conflicts). We interpret these findings from the perspective of a critique of ideology that is two-tiered. First, in an immanent critique of the material, we focus on the logic of the ideas expressed therein, including "internal assumptions, categories, problematization and argumentation, with a view to disclosing empirical inadequacies, theoretical inconsistencies and anomalies, silences, exclusions, contradictions or other defects" (Jessop and Sum 2016, p. 107). Second, we identify the privileged interests and forms of social domination that serve particular interests, as well as the more broad-based institutional (cultural, technological, political) frameworks that uphold these ideas (ibid.). Together, these steps amount to a critique of ideology that brings to light both the discursive logic of ideological strategies and their social and material bases. The analysis shows how these combine to create ideological strategies that are convincing, coherent narratives of sustainable biomass use and contribute, in a more general sense, to consolidating the larger political project of ecological modernization.

Results: ideological strategies regarding the sustainability of biomass use in the German bioeconomy

Our analysis identified four principal ideological strategies employed to create and uphold the image of sustainable biomass use, namely: seeking managerial solutions, relying on technical innovation, relegating solutions to the future, and obscuring the materiality of nature. The four strategies are described and discussed in the following subsections. References to source material refer to the numbering in Appendix A.

Seeking managerial solutions

'Seeking managerial solutions' conveys the idea that sustainability can be attained through better management of procedures and technical processes, for example through biomass monitoring: "First, the bioeconomy needs to be better described and mapped out in accordance with the principle: 'what you can't measure, you can't control'" (B.50). This includes suggestions for creating databases and developing appropriate (quantitative) methods for monitoring biomass flows and bio-based products (A2.18; A2.10: 285); "mathematical methods and models, as well as targeted experiments regarding the matter and energy cycles [that] help us to regulate food production [based on insects as novel sources of biomass]" (B.60). Managerial solutions are also exemplified in experts' proposals to manage the involvement of actors in the bioeconomy by engaging with stakeholders from business, academia, consumer groups, and the general public. This may entail governance measures such as "private regulation [e.g., voluntary certification of products], supply chain laws, and hybrid forms of governance" (B.44) as well as participatory tools such as citizen science, regional innovation labs or future scenarios (B.3), to the extent that the latter are conceived of as means of ensuring that the bioeconomy runs smoothly, rather than ways to address the fundamental issues of what sustainability means and how (else) it could be achieved.

A first ideological component of this focus on managerial solutions is the tendency to suggest that the goals of the bioeconomy are objective and unambiguous. The emphasis is on formally structured knowledge frameworks such as quantitative calculations of biomass availability (e.g., residues of selected products of agriculture, forestry, and fisheries); economic evaluations and definitions of economic indicators; and systematic monitoring of the bioeconomy and its effects on land and resource use, demand for water, and CO_2 emissions. At the same time, the ideological strategy is based on the common sense assumption that quantification and measurement provide objective indicators of sustainability. This is illustrated by quantitative calculations pertaining to biomass availability that lack both a common definition of key terms such as 'sustainability' (A.2.11, A.2.14, A.2.16, A.2.21), as well as a standard or operational definition of 'bioeconomy' (A.2.21; A.1.10). Without these common reference points, calculations and quantified measures become collections of numbers that are used to reach uncertain conclusions on sustainability based on discrete biomass flows, and specific shares of bioeconomy products. For example, while some monitoring studies exclude entire product groups and sectors because the biomass they contain and/or process does not substitute fossil resources, other studies base their calculations on all manufactured products and services that contain at least 10% biomass (A2.14: 11, A2.10). Thus, despite a managerial emphasis on finding adequate methodologies and data in biomass monitoring, the researchers involved in the monitoring process themselves recognize that "for regular statements to be made on biomass potential and current use, continuous and more precise reporting is required. […] At present, there is a lack of suitable organizational systems and data structures for this purpose, and of clear responsibilities among the institutions providing and receiving the data" (A2.1: 263). As a result, methods such as Life Cycle Analysis (a method for assessing environmental

impact based on material use) are in fact not "a viable basis for frequent bioeconomy monitoring" (A2.2: 107).

A second ideological component of the managerial strategy is that it conceives of sustainability as a question of adequate problem solving, leaving out other aspects of sustainability such as equitable access to resources. As such, it obscures how the tools and methodologies that it proposes relate to conflicts of interest and conflicting goals such as economic growth and ecological sustainability. For example, the bioeconomy monitoring process is oriented towards indicators of economic efficiency and effectiveness. Although some account is taken of social and ecological aspects, sustainability is first and foremost evaluated from the point of view of economic sustainability. An entire branch of the monitoring process is devoted to this aspect, to which all other branches are expected to refer back to. A third ideological element is linked to the participatory methods employed. Even though 'participation' suggests deliberative democratic processes in the definition and establishment of the bioeconomy, existing participatory spaces have no decision-making power. Instead, they are used as a tool to inform citizens about the bioeconomy, without offering them the opportunity to change the trajectory of bioeconomy policies.

The focus on managerial solutions obscures the relationship between the proposed solutions and broader social and political issues, resulting in a depoliticized perception of society–nature relations. This helps create consent for the bioeconomy as a political project by bracketing out its conflictive dimensions such as conflicts over access to land and water in areas where biomass is extracted. To create this impression, bioeconomy policies and politics are seen not as an outcome of sociopolitical debate but simply as the application of regulatory tools and scientific expertise to achieve a well-managed outcome. From this perspective, it is unsurprising that the focus of political debate on the German bioeconomy, instead of widening, is narrowing to the point where politics become a matter of management. This is reflected in the substantial number of Bioeconomy Year of Science contributions in which the featured bioeconomy experts engage with problems of politics as an issue of technocratic governance. For example, experts may advocate concrete "forms of governance for a new 'ethical' power [whereby] consumers use their power to influence trade to impose norms such as peace and sustainability" (B.44), while others conceive of politics as simply "sources of legitimacy" to be mobilized when needed: " […] when anti-democratic attitudes are on the rise, it is crucial that the bioeconomy be accompanied by regulatory [ordnungspolitische] measures that allow for enabling, correcting or preventing missed goals for public well-being. Let's do it!" (B.40).

Relying on technological innovation

This ideological strategy creates and maintains the image of a sustainable bioeconomy by presenting technological innovation as a solution for complex socio-ecological problems. As stated by a researcher on sustainable land use and bioeconomy, "the bioeconomy discourse is refreshingly solution oriented. Buzzwords such as "biologization" stand for technology-driven societal change that, in conjunction with other innovation trends such as digitalization, open up new pathways to sustainable development" (B51). Presenting every sustainability problem as a technological one erases from view a host of social relations such as agricultural production, (auto)mobility or (resource) consumption. Technologies are presented as the sole mediating mechanism between ecological frontiers and societal expectations. From this perspective, sustainability is mainly understood as being achieved through targeted technological interventions to address discrete issues such as resource scarcity, biodiversity, water and land use, and soil quality (A1.5). This is strongly reflected in the frequent links made between the Bioeconomy Strategy and the High-Tech Strategy in official policy documents. Digital technologies, including biotechnologies, are the innovations most frequently extolled as tools for the rationalization of biomass use; others include robotics, mathematical modeling, the development of new sensors, bioreactors, computer modeling, and predictive statistical models (B.60; B.13; A1.6: 39; A1.3: 35).

As an ideological strategy, relying on technical innovation is anchored in the formally structured knowledge associated with the development and implementation of the technologies themselves. These range from laboratory techniques to produce cultured meat to meet increased demand for meat (B.46) to "natural breeding techniques" that produce dandelion-based rubber "without targeted molecular manipulation" (meaning that dandelion biomass was not 'genetically modified') (C1.11). In monitoring studies, references to specific innovations are mentioned to account for uncertainties in calculations or to indicate the likely availability, in the future, of new and purportedly more efficient options for biomass use (A2.1; A2.10; A2.12; A2.15; A2.16). At the same time, this ideological strategy is also based on the common sense notion frequently found in the documents we reviewed that modifying nature sustainably is only a question of deploying the right technology, since new technologies are always more efficient: "One could close the [meat] slaughterhouses and instead satisfy the demand for meat more efficiently via biotechnologically produced meat fibers" (B.46). This notion is particularly prominent in policy documents which link sustainable biomass use to biotechnologies, digitalization, or circular production (e.g., A1.6: 19, 29; A1.5:7; A1.2:8). This focus on technologies is not limited to new techniques, or the scientific rationalization

of production processes or materials, but also encompasses socio-technical innovations such as cascade use of biomass that may require extensive/large-scale reorganization of, for example, value chains and information flows. (A2.1: 7). "A sustainable bioeconomy aims to achieve closed-loop material cycles by using resources more efficiently and minimizing waste and emissions. Along the entire value chain, innovative process technology is required. This applies to intelligent product design, production or the cascade use of bio-based resources" (A1.2: 61). Policy documents assume that there is 'new biomass potential' in new biogenic resources, aquatic culture systems, bioengineered resources and, particularly, in waste products (A2.1: 1): "In the system of the bioeconomy, circular and residue economies that are able to avoid creating byproducts and residues or can give them high-value uses are increasingly important" (A1.2). The dandelion-based tire is exemplary of this approach of "sustainability through technology" (C1). Molecular biology (genome sequencing) is used to reengineer a plant not only as a source of novel bio-based materials, but also to produce ecological and social benefits, including reduced CO_2 emissions through shorter supply chains, and an end to reliance on production systems characterized by poor labor conditions, such as rubber plantations in Asia (C2). A further advantage claimed for dandelion-based biomass is that it does not create conflicts with food production, since it is derived from plants that have been technologically optimized to thrive on so-called marginal lands.

Similar to managerial solutions, the focus on technological solutions to social problems helps to create consent for the bioeconomy by framing socio-ecological conflicts (e.g., divergent land-use interests, biodiversity loss, resource scarcity) as non-conflicts, i.e., as technical issues. This aspect was very present in many of the Year of Science contributions, which associated sustainability in the context of the bioeconomy not only with managerial governance strategies, but also with the use of technologies such as Computational Political Economy Models (CGPEs). "These are ecological–economic models, seamlessly integrated with mathematical models of economic policy decisions. These models allow simulation under a range of model beliefs of what would really happen when a specific policy program, such as regulation of CO_2 emissions or investment in education or infrastructure, is implemented. Digital graphical interfaces enable interactive use of the models by stakeholders (citizens), whereby they adjust their expectations (stakeholder beliefs) regarding policy impacts based on the model outputs. Conversely, these also allow for model learning, i.e., model beliefs can be adjusted based on the practical stakeholder knowledge that is communicated" (C.61).

Relegating solutions into the future

Many of the visions regarding the bioeconomy entail futuristic images in which biomass transforms the environment in a positive, sustainable manner. These are presented as "… not necessarily the future of a distant galaxy, [since] this could also be the future of our Earth: a gigantic mega-city, [where] areas for food production, as we know them today, no longer exist" (B.4). "In the future people may feed on a range of products, obtained from phototrophic biofilms, [and] produced regionally, ecologically and sustainably in biofilm reactors" (B.36). Dandelion rubber is also iconic of this strategy, as conveyed in the developing company's slogan: "tires for the future: we develop sustainability" (C1).

This results in an ideological strategy premised on drawing attention away from present conflicts: the truly sustainable and viable bioeconomy is yet to come. It draws on and builds upon the managerial and technological strategies, portraying the biomass transition as plausible in accordance with the development of managerial and technological tools. "Integrated [biomass] accounting will be possible when one can measure or precisely estimate the use of biomass over its entire life cycle, from production to reuse, and the application, effects and feedback effects of bioeconomic processes" (A1.6: 3). But unlike the above strategies that are anchored in the legitimacy of formally structured knowledge frameworks themselves, this strategy draws support from this legitimacy but, crucially, relies upon a vague common sense notion of societal progress. In contrast to specific technologies or managerial strategies, the legitimacy of research plays a mainly promissory role, whereby "… structural change from an oil-based to bio-based economy that can enable economic prosperity at the same time as social and ecological sustainability" will be made possible by "… strengthening the knowledge-based bioeconomy through targeted promotion of research and innovation" (A1.1: 4–5). This optimistic vision of progress through research is often found in official policy documents, as well as in the Year of Science contributions. It is, however, dampened somewhat by more cautious assessments in the reviewed documents on biomass monitoring, such as the following: "The development of the bioeconomy will be largely determined by innovations whose characteristics and effects are still inadequately understood" (A2.16: 10). Critical statements like these underscore the fact that the image of sustainability is not created by the coherence of the discourses we identify, but despite contradictory evidence and doubtful voices.

Relegating solutions to today's problems to the future contributes to political consent by rendering the precise contours of sustainability vague and undefined, thereby attenuating potential conflicts. Several of the policy documents reviewed invoke various types of social change, including socio-technical change, reorientation towards a

bioeconomy, societal and economic change, technological innovation, new forms of agriculture, the move away from a fossil-based economy, and so forth. However, they rarely define change more concretely, circling instead around the notion that these transitions are per se sustainable. Consent may also be encouraged by presenting the bioeconomy as the only possible solution to contemporary ecological problems: "On this necessary but obviously not easy path, no ideologically tinged […] perspectives on an allegedly 'ideal world' of the past will help us, but only a critical reappraisal of the problems […] and knowledge-based proposals for solutions for the future" (B.14). Here, we also see that consent can build on a vague reliance on something desirable, without asking for whom, and without identifying agents of change beyond vague references to, for example, "scientists and citizens" (B.58). This emphasis on the role of experts in orchestrating the future is also highlighted by the way that experts were portrayed in the Bioeconomy Year of Science as "Leaders of Change".

Obscuring the materiality of nature

A fourth ideological strategy for creating an image of sustainable biomass use consists in obscuring the materiality of nature, i.e., its biophysical qualities. In this respect, it is notable that 'biomass' was not defined in official policy documents until 2020 and that different policy documents employ a range of apparently interchangeable terms, including 'biomass', 'biogenic resources', or 'renewable primary materials' (e.g. A1.6; A1.5; A1.4; A1.3). The Bioeconomy Strategy 2020 defines biomass as "… in a narrow sense photosynthetically produced organic substances; in a wider sense the amount of matter of all plant and animal life forms and their organic products [including] residual and waste materials such as bio-waste from households, animal production, and the production of food and animal feed […]" (A1.6: 58). These definitions omit the fact that not all forms of biomass can be used for the same purpose. For example, not all biomass can be used for agrofuel production but only specific crops or particular parts thereof. Similarly, the vast number of potential biomass applications suggested in public statements such as those featured in the Year of Science tend to cement an image that all kinds of biogenic material are useful, and that any kind of renewable material is sustainable. An emphasis on biomass as an important part of a sustainable circular bioeconomy (A1.1: 4) taps into common sense understandings that recycling is a positive measure. However, the obscuring of the materiality of biomass risks overemphasizing the potential of "waste and residues," as a driver of the bioeconomy since estimates suggest that at most 34% of waste materials in Germany remain unused (A2.17: 14–17).

Furthermore, the monitoring studies we reviewed assess the potential for biomass-based transformation differently from the policy documents. In contrast to what is suggested by policy statements such as, "with the expansion of the bioeconomy, the resource base of the economy will be sustainably oriented, and fossil raw materials replaced" (A1.6: 10), monitoring studies do not consider the availability of material that would be needed to transform all or most of the existing economy based on fossil raw materials to a biomass-based economy. Instead, the intention of monitoring studies is to identify discrete economic activities where fossil raw materials could be replaced by biomass, as well as to map the existing use of biomass in the economy. According to a researcher involved in the monitoring, this means that, "…there have only been occasional comparisons with national biomass potential including flows of imports and exports, and the results are very incomplete, especially in the field of biogenic residual materials. It is currently possible to evaluate the temporal development of individual biomass sources and their use in occasional cases, but no overview is possible" (A2.1: 6). The partial nature of this quantitative assessment is further underlined by the fact that many of the processes regarded as central to the bioeconomy are currently undefined. For instance, there is currently no agreed formal or legal definition of 'cascade use', despite many assertions in policy documents that "through combined and cascade utilization of biomass, raw materials can be completely used in a high-quality way within the circular [bio]economy" (A1.2). Monitoring studies of input–output ratios in recycling or cascade-use focus on exemplary products such as the EPAL Euro Pallet. Moreover, calculations of material consumption and sustainability for these chosen products relate exclusively to the end product, thereby excluding material and energy expenditures during production (A2.10: 10). Thus, assessments regarding sustainability do not consider entire biomass-based production processes. Furthermore, different studies adopt very different approaches to measurement, such as regarding the selection of material aspects of biomass to include in the calculations: while some studies consider the total amount of biomass contained in a product (A2.10), others include only biomass products that could actually replace fossil products (A2.14). Thus, perceptions of sustainability, which determine whether or not a product is factored into the bioeconomy, vary considerably depending on the methodology that is adopted.

Understandings of nature based on formally structured knowledge play a key role in obscuring, simplifying or abstracting from the material properties of nature through the very notion of biomass itself. Biomass is itself a homogenizing notion that obscures the biophysical materiality of nature to the extent that it erases from view particular qualities of nature in favor of comparable mass or energy units. It is a concept that is attractive in the context of policy and

economic calculations, apparently rendering the complexity and constant transformations associated with living nature a tame and controllable (bio)mass. Moreover, common sense understandings of biomass based on intuitive understandings and assumptions also often overlook the biophysical materiality of nature. Examples of this may be seen in statements by experts featured in the Year of Science, in which an intuitive spatial dimension implicitly plays a key role in assessing the contribution of biomass use to sustainability: the unspoken assumption seems to be that small organisms as sources of biomass (e.g., microorganisms such as bacteria or microalgae) entail small amounts of biomass and can therefore be used and upscaled sustainably. In contrast, Year of Science contributions that focus on biomass use at a much larger, national scale are less sanguine: "The climate-change impact of the bioeconomy is higher than its contribution to value-creation or employment. The climate footprint of German consumption of biomass-based products is about one fifth (18%) of the entire climate footprint and, based on current trends, will [not decrease significantly in the future]" (B.47).

This tendency to abstract from the physical qualities of living nature or to simplify the way it is presented may contribute to political consent by drawing attention away from, and thereby attenuating socio-ecological conflicts pertaining to the biophysical materiality of nature. By ignoring the availability and ecological effects of specific, material forms of biomass, as well as associated conflicts of use, biomass becomes a cake that we can all have while eating it too: "Biomass briquettes give developing countries the possibility to use waste materials to produce in a more climate-friendly way and at the same time increase people's quality of life and protect our forests—a win–win situation for people, nature and the economy!" (B.35). This image is achieved not only by focusing on biomass use in specific contexts, to solve a specific problem, or in small amounts, but also by drawing on the other ideological strategies for support, whereby problems or conflicts that arise are considered 'solvable' by improved management, technological innovation, or unspecified future developments. However, the economic goals of industrial efficiency, scalability, and enhanced performance translate into an inherent tension between production and the reproduction of these 'renewable resources', as illustrated by the example of dandelion-based rubber: in the present pilot product, sustainability gains—based on regional production on marginal lands, and replacing transnational supply chains with short transport distances—seem plausible. However, if production were upscaled, it is questionable whether enough 'marginal' land would be available. To achieve the current goal of replacing only 10% of the company's tree-based rubber production by dandelion, 40,000 ha of land would be needed (C2). To meet the entire current global demand for rubber with dandelion-based rubber would require a land area equivalent to two European countries: Austria and Switzerland (C2). However, when the dandelion-based commodity is showcased in the media as an iconic example of the potential of the bioeconomy, the implications of upscaling or other possible adverse second-order effects are left out.

Discussion: ideological strategies, ecological modernization, and the materiality of nature

Our results suggest that the four ideological strategies we identify uphold an image of sustainability in the discourse on biomass in the German bioeconomy. The strategies rely on formally structured knowledge, including calculations, quantified values, and models to create a sense of predictability and rationality that legitimizes the project of biomass-based transition, which claims to achieve sustainability through proper management, research, and innovation, and especially the future promise of new technologies. The working of this logic is underpinned not only by the way information regarding biomass use and the bioeconomy is simplified in the context of policy discourse or in information directed to a wider public. Crucially, it is also upheld by a host of widely held common sense assumptions that associate new technologies with greater efficiency, associate 'the future' with a vague notion of societal progress, and assume that anything 'green', i.e., any renewable resource, is necessarily sustainable. However, these common sense arguments cannot be understood solely by analyzing the internal logic of their narratives regarding biomass use. Rather, as critical theories of ideology suggest, common sense and the ideological strategies it enables should be understood in the wider societal context. This includes the institutions or 'ideological apparatuses' that uphold and reproduce these strategies, including the various ministries charged with implementing the German bioeconomy; national policy strategies; and the governmental, research and media institutions that contribute to their implementation. These also encompass institutions associated with the larger 'ecological modernization' project (Huber 1993; Hajer 1995) beyond Germany, including the Organization for Economic Cooperation and Development and the UN bodies responsible for implementing the Sustainable Development Goals; as well as large environmental NGOs (Hajer 1995, p. 101), such as the World Wildlife Fund in its role as promoter of the Bioplastic Feedstock Alliance. In our study of biomass in the German bioeconomy, such links were evident, for example, in the fact that all Year of Science contributions made explicit reference to at least one of the UN Sustainable Development Goals. Here, biomass use is deemed sustainable through its close association to the ideologically laden project of ecological modernization that presents

sustainability as inevitable (Weber and Weber 2020). From a Gramscian perspective, the bioeconomy discourse regarding biomass use and the understanding of sustainability that underpins this discourse can be seen as part of a larger eco-modernist 'historical block' that has incorporated aspects of its criticism selectively and binds together social groups beyond the field of bioeconomy policy, including certain factions of capital, parts of the environmentally conscious middle class, business and media leaders, and so on, that uphold a particular way of organizing society–nature relations more generally. In particular, the ideological strategies we dub 'seeking managerial solutions' and 'relying on technological innovations' dovetail with the broader framework of ecological modernization. Our findings also support claims in the literature on post-politics that, in sustainability transitions, political contradictions are reduced to policy problems and expert solutions, subsequently legitimated through participatory processes that fail to offer possibilities for radical or far-reaching change (Blühdorn 2015; Raco 2015). Furthermore, our findings highlight the importance of 'relegating solutions into the future', which is discussed by the literature on the sociology of expectations (van Lente 2012) as an ideological strategy lending credence to the bioeconomy.

In addition to these three strategies discussed elsewhere in the literature, our analysis identifies a further ideological strategy that stabilizes the project of the bioeconomy, namely the strategy of obscuring the biophysical materiality of nature. We suggest that this is an important aspect of discourse on ecological modernization that is rarely made explicit, but which the discourse on biomass use, as presented in this paper, is exemplary of. We show that the sidelining of the materiality of nature is done in a way that upholds various core elements of the eco-modernist political project, including presenting the materiality of biomass only in relation to selective contexts; sidestepping the issue of upscaling; or alluding to its materiality only indirectly, by focusing instead on the technologies to modify this materiality and thereby creating the sense that nature can be modified at will. Presenting the bioeconomy as renewable and therefore sustainable detracts attention from biophysical aspects, cementing the idea that economic growth via the technical optimization and valorization of biomass and ecological problems are not contradictory: the prefix 'bio' fits comfortably with the capitalist 'economy'.

At the same time, to the extent that the biomass-based bioeconomy and various kinds of other 'green' economies are seen as a plausible economic growth strategy, the materiality of nature is not only the object of an ideological strategy to create an image of sustainability, but also an increasingly large elephant in the room that may prove more and more difficult to obfuscate. As we have shown, the discourse of sustainable biomass use 'works', because it is confined to discrete areas of the economy and a handful of exemplary commodities, portrayed as based on the use of small amounts of biomass, and premised on promises of future technological fixes. But what of the political and economic factions that want to, or must make good on increasing biomass use at a larger scale as suggested by various economic and political actors in the German bioeconomy, including the industrial clusters that explicitly seek out large-scale biomass-based growth in areas such as agriculture, forestry, fishery, or bioenergy (*Bioökonomie—BioEconomy Cluster e.V.*)? To the extent that the bioeconomy is upscaled, the ideological elements we identify may no longer be secure. The material contradictions are striking, as illustrated by the dandelion project, and suggested by various scholarly analyses. They include the fact that in production processes based on living nature, the reproduction of the raw material, i.e., biomass, cannot keep pace with the requirements for production and consumption of goods and services (Martínez-Alier 2002), due to the dramatic difference between the pace of production and density of energy inputs of fossil-based resources on the one hand and biogenic resources on the other (Giampietro 2019). Although the ideological strategies identified in this paper retain their functionality at present, they may lose their capacity to generate political consent if and when the biophysical contradictions of the bioeconomy project become too starkly apparent. In this case, obtaining active consent might be more difficult, and the obfuscation of the materiality of nature may become a politically destabilizing force, undermining both the bioeconomy and the larger political project of ecological modernization.

The difficulty of upscaling biomass use is by no means the only threat to the stability of bioeconomy, which is not a monolithic project and is politically contested. While the bioeconomy project largely relies on this notion of the technical optimization of nature, it is important to recall that notions of predictability and control of nature, as found in formally structured knowledge and common sense understandings are not monolithic. Thus, critical scientific research also questions whether such representations of nature are not largely at odds with reality (Merchant 2015) and this acknowledgment of the materiality of nature as 'autonomous' could potentially inform alternative understanding how humans relate to the rest of nature within formally structured knowledge contexts (Merchant 2015, p. 7). Likewise, the prevalence of multiple ecological crises such as climate change and biodiversity loss contribute to questioning common sense narratives regarding technofixes and the control of nature. Furthermore, other definitions of sustainability exist, such as those based on sufficiency, although they are not dominant in sustainability discourse. These alternative ways of understanding and practically relating to the materiality of nature are important points of departure for developing what Gramsci referred to as 'organic ideologies' or a 'philosophy of praxis'. This would entail using new

common sense worldviews and practices to challenge the dominant ideological strategies (Rehmann 2013, p. 130ff.). An example of this in the context of biomass production are the interventions of international environmental movements that politicize the 'biofuels' debate, reframing the issue of biomass as a choice of 'food vs. agrofuels' and thus challenging common sense views such as those stating that all things 'bio' are sustainable. Such 'good sense' propositions (Gramsci 2012a, p. 1397) challenge common sense notions by addressing the biophysical complexity behind the abstract notion of biomass, rendering visible concrete uses of, and conflicts surrounding access to water or land. Given the centrality of abstracting from the materiality of living nature as an ideological strategy for upholding the bioeconomy, we suggest that developing good sense notions will entail questioning current representations of nature and developing alterative understandings of nature—through, for example, practices such as farming or gardening, but also as a result of experiencing the everyday effects of the ecological crisis. These alternative understandings may involve rejecting the inherent abstraction of seeing all of living nature as 'biomass' and instead rendering visible the specific, locally present trees, insects, fields, and ecosystems as the basis for alternative society–nature relations.

Conclusion

In this paper, we depart from the patent contradiction between discourse on the German bioeconomy claiming that increased biomass use will enable a sustainable transition to a bio-based economy, and the plethora of evidence suggesting that increased use of biomass is untenable due to its limited availability and the negative socio-ecological effects associated with expanded use. To better understand how an image of sustainable biomass use remains possible in the face of this evidence, we employ the analytical framework of ideology critique. We identify four ideological strategies, namely seeking managerial solutions, relying on technological innovation, relegating solutions into the future, and obscuring the materiality of nature, and describe their role in the creation of political consent for the political project of the bioeconomy as part of a larger project of ecological modernization. We show how these ideological strategies rely on the interplay of both formally structured and common sense systems of knowledge. We adopt a Gramscian perspective that highlights the role of such common sense understandings, thereby shedding light on the importance of unrationalized beliefs, assumptions, contradictory views, omissions, and inconsistencies for creating and upholding an image of sustainability in the context of a largely technology-centered debate on biomass use in the bioeconomy. We show how all strategies contribute to creating consent for the larger political project of ecological modernization. A particular contribution of this paper to the literature on the bioeconomy and ecological modernization is the finding that 'obscuring the materiality of living nature' is a key component of these political projects. This is a strategy that merits more explicit analysis, since it not only suggests why current ideological strategies may cease to be effective in creating political consent, but also provides a starting point for countering these ideologies on the basis of new practical relationships with the materiality of living nature.

Appendix A: Primary Sources

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