

# **The multitudes of bioeconomies: A systematic review of stakeholders' bioeconomy perceptions**

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## **Abstract**

‘Bioeconomy’, the use of sustainably produced biomass and the application of biotechnologies, serves as an umbrella term for highly diverse interests and perspectives by a large number of stakeholders involved and by broader society. Consequently, research on stakeholder perceptions of the bioeconomy has increased, investigating questions of, e.g., underlying normative assumptions, political legitimacy and participation, or consumer acceptance. In order to identify the current state of research and avenues for further research, we conduct a systematic literature review of stakeholders' bioeconomy perceptions. To this aim, we developed a mixed-methods approach based on the inductive coding of research articles. The review finds an overall dominance of biotechnology and resource themes, and a strong focus on research, policy and industry stakeholders. A lack of ecological and societal concerns, against the background of few research works on actors from civil society, suggests a gap between the bioeconomy as a sustainability concept and the perceptions of stakeholders involved. Overall, stronger consideration of societal stakeholders is required both in research and policy.

**Keywords:** Bioeconomy; Stakeholders; Perceptions; Bioeconomy visions; Stakeholder preferences

## **1. Introduction**

Growing concerns about environmental degradation and climate change, resource depletion and social inequality have given rise to several policy visions for transitioning towards a more sustainable economy and society. One of them is the concept of the “bioeconomy” or “bio-based economy”. Prominently featured in policy, the term encompasses diverse strategies for reforming agriculture and forestry, replacing fossil resources by regenerative biological resources in industrial production, advancing biotechnology and life sciences, or promoting local and self-sufficient consumption behaviors [e.g. Federal Government of Germany, 2020, European Commission, 2018, OECD, 2018]. Thus, the term describes a complex and ambiguous concept, the implications of which must be carefully understood when assessing the bioeconomy's potential contribution to sustainable development.

In its current interpretation, the bioeconomy concept was introduced by the Organization for Economic Co-operation and Development (OECD), in two reports on the socio-economic potentials of utilizing biomass and biotechnology from 2004 and 2009 [OECD, 2004, OECD, 2009]. These reports initiated the development of several dedicated national bioeconomy strategies. In the European Union (EU), the concept of a “knowledge-based bio-economy” was developed in 2007, refining the OECD’s approach to focus on innovation and commercialization options in the life sciences [Federal Ministry of Education and Research, 2007]. Since then, the EU has published two more strategies [European Commission, 2018, European Commission, 2012], which emphasize a link between bioeconomy and sustainable development, highlighting ecological and social concerns as well. Next to multiple countries and international organizations, also sub-national regions and communities have developed dedicated strategies, such as the Spanish state of Andalusia [Junta de Andalusia, 2018] or the German state of North Rhine-Westphalia [Ministerium für Kultur und Wissenschaft des Landes NRW, 2012]. Such strategies more often set their focus on regionally specific concerns such as, e.g., higher efficiency in the use of locally available raw materials, conflicts around land use, or job creation in rural areas. Thus, approaches to the bioeconomy differ greatly in terms of their intended objectives and policy measures, but generally refer to sustainable development as the overarching paradigm.

More recently, the role of society in a bioeconomy has emerged as a widespread policy concern. The envisioned changes to the management of natural resources are profound, and require a clear understanding of the positions of involved stakeholders and society at large. The EU’s 2018 strategy highlights engaging economic stakeholders in the development and commercialization of technologies and products [European Commission, 2018]. The first German bioeconomy strategy of 2010 turns to earlier stages of the bioeconomy transformation and identifies a societal consensus as a precondition, calling for adequate participation processes [Federal Ministry of Education and Research, 2010]. In the subsequent 2020 iteration of the strategy, furthermore, the need to research societal change processes is underlined [Federal Government of Germany, 2020]. Overall, the different stakeholders are identified as key drivers of the bioeconomy and its potential contribution to sustainable development.

In the same vein, research highlights that the bioeconomy transformation is also a process of societal change [Johansson & Henriksson, 2020, Priefer & Meyer, 2019, Mukhtarov et al., 2017, Peltomaa, 2018, Hausknost et al., 2017], with different stakeholders being key for how the bioeconomy is developed and governed [e.g. Borras Jr et al., 2016, Lynch et al., 2020, McCormick & Kautto, 2013]. Meyer 2017 specifically identifies lacking social acceptance, new societal conflicts and the potential for disappointment as considerable barriers for the bioeconomy [Meyer, 2017]. Thus, research on stakeholder perceptions is vital in developing and implementing a bioeconomy.

However, such research is as diverse as the bioeconomy policy strategies. The rapidly growing number of works encompass conceptual articles and policy reviews, as well as surveys and expert interviews of specific stakeholder groups or regarding a specific sector or issue of the bioeconomy. Moreover, the relatively recent bioeconomy concept touches upon many related and well-researched issues, such as the nature-human relationship, attitudes towards agriculture and technology, responsible consumption behavior, and the sustainability paradigm [Birch et al., 2010, Priefer et al., 2017], as well as the circular economy concept [Bressanelli et al., 2020]. Accordingly, research on bioeconomy perceptions is anchored within several disciplines and research communities, many of which have only recently begun to relate their work to the

bioeconomy concept. Thus, research works differ substantially in terms of their objectives, concepts and methods, hindering an overall comparison or generalized conclusions on stakeholder perceptions of the bioeconomy as opposed to case-specific observations. This constitutes a gap both in research and policy. Especially, since research suggests that individual issues and understandings of the bioeconomy are linked to specific actor groups [Birch, 2016, Vainio et al., 2019], who participate in the policy debate to differing degrees [e.g. Dieken & Venghaus, 2020, Mukhtarov et al., 2017].

This paper aims at providing a comprehensive overview of the scientific literature on stakeholder perceptions of the bioeconomy in order to enable both the assessment of the current state of research and the streamlining of further research in this field. To this objective, a conceptual framework for describing key characteristics of stakeholders' bioeconomy perceptions across diverse works of research was developed and applied in a content-based review of empirical research. By systematically comparing results on stakeholder groups and bioeconomy perceptions, we provide valuable insights on the need for more in-depth and more representative research and the practical applicability of the bioeconomy concept. While the bioeconomy concept is closely linked to sustainable development, this is identified as only a marginal aspect of stakeholders' perceptions. In Section 2, the framework for the systematic literature review is devised against the background of a short overview of conceptual literature on the bioeconomy and reviews of policy strategies. The results of the comprehensive review of empirical research articles on bioeconomy perceptions are presented in Section 3 and discussed in Section 4. Finally, conclusions are drawn from the state-of-the-art analysis of research on bioeconomy perceptions in order to suggest avenues for further research (Section 5).

## **2. Conceptual and methodological framework**

In order to provide a comprehensive overview of the scientific literature on bioeconomy perceptions, we conducted a systematic literature review by developing and assigning content-based codes to documents and analyzing them using a mixed-methods approach. This section is concerned with the methodological framework for reviewing empirical research on bioeconomy perceptions. In section 2.1, the bioeconomy concept will be introduced based on a short summary of policy reviews and conceptual literature on the bioeconomy. In the subsequent section 2.2., we will present our approach for data selection. Finally, building on those two steps, we will develop an analytical framework for the content-based analysis of empirical research articles on bioeconomy perceptions (section 2.3).

### **2.1. The bioeconomy concept**

Comparing and analyzing findings on bioeconomy perceptions requires, first and foremost, a clear understanding of the concept. However, as argued in the introduction, the term bioeconomy is not unambiguously defined. Thus, we preface the development of the research framework with a brief overview of the concept based on conceptual literature and policy reviews. The increase in bioeconomy policies worldwide has driven a similar rise in the publication of policy reviews on objectives and activities which are characterized as bioeconomy-related. Also, a number of conceptual works critically engage with the term itself

in an attempt to clarify and evaluate bioeconomy policy and research approaches. Both types of publications constitute an important frame of reference for empirically researching bioeconomy perceptions. Thus, we briefly summarize bioeconomy conceptualizations and key issues from conceptual and review literature before introducing our research approach.

More strongly than other types of research works, conceptual articles aim to define the bioeconomy itself. The concept is theorized in terms of central lines of thought [e.g. D'Amato et al., 2017], critically explored regarding socio-political implications [e.g. Goven & Pavone, 2015], or refined as an applicable analytical concept [e.g. Liobikiene et al., 2019]. The bioeconomy is conceived as a grand vision for the development of society and economy, which encompasses specific policy objectives such as economic growth or mitigation of climate change. Based on these works, research has come to differentiate between multiple, potentially conflicting definitions of the bioeconomy. As discussed in a preceding work [Dieken & Venghaus, 2020] and by other literature works [Giurca, 2020, Kleinschmit et al., 2017], bioeconomy understandings are often characterized in terms of their different assumptions regarding sustainability and the economization of nature. One such conceptualization was developed by Bugge et al. based on a review of bioeconomy research literature [Bugge et al., 2016], and has since been regularly employed as an analytical lens in empirical research [e.g. Stern et al., 2018, Peltomaa, 2018]. The authors identify three distinct but related interpretations of the term: bio-technology, bio-resource and bio-ecology. This conceptualization regards the prime reasoning and beliefs behind the bioeconomy (the relation between the objectives of growth and sustainability), and how they translate into the design of the bioeconomy (specifically, technological innovation, cascading use of biomass, and circular production and consumption processes, respectively) [Bugge et al., 2016]. Thus, this conceptualization is very useful in capturing crucial differences in stakeholder perceptions.

In turn, policy reviews are more practically oriented when defining the bioeconomy, focusing mostly on already existing policies and governance structures relevant to this new concept [e.g. Dietrich et al., 2017]. Generally, literature finds a fragmentation of bioeconomy governance across multiple policy fields and economic sectors. This is explicitly analyzed and criticized by Kelleher et al. [Kelleher et al., 2019]. Staffas et al. conduct a review of national bioeconomy strategies to identify the potential priority areas [Staffas et al., 2013]. They find a wide range of policy fields from agriculture and food policy to biotechnology, energy and industry. Thus, the bioeconomy is also defined according to several distinct economic activities from primary biomass production to the consumption of bio-based products.

Beyond these rather generalized conceptualizations of the bioeconomy, some research works highlight the necessity to view the bioeconomy in its specific context. Bioeconomy can be understood as a territorial configuration with very specific local conditions [e.g. Birch, 2012, Horlings & Marsden, 2014, Wohlfahrt et al., 2019]. So, in addition to comparing geographical coverage of research, the scope of the bioeconomy is also identified as a relevant characteristic of bioeconomy perceptions. The issues raised in these conceptual and review articles inform the development of research questions guiding our literature review (section 2.3), as they indicate on which aspects stakeholder perceptions can diverge.

## **2.2. Data selection**

Against the background of the bioeconomy's conceptual complexity and ambiguity, the central research challenge for analyzing perceptions is the definition and delineation of the concept. Thus, we determined an important precondition for the selection of the dataset for the literature review. Since a vast amount of literature is arguably relevant to the bioeconomy, we chose to focus exclusively on research that self-identifies as dealing with “the bioeconomy”, i.e. literature that explicitly aims to investigate perceptions of this concept. To this objective, we compiled the data for the literature review by conducting a search query for the term in a research database.

The choice of a research database was informed by our intent to review empirical research on bioeconomy perceptions. To begin with, our interest in empirical research suggests a comparison of journal articles, since these constitute the primary scientific format for original research. Thus, we needed to be able to specify our search for the type of publication. Moreover, since bioeconomy constitutes an increasingly popular buzzword, the search query is improved by being able to search in key parts of the text, excluding literature which only references the term (e.g. in citations or affiliations) but does not regard the bioeconomy as object of research itself. The database Web of Science met these criteria by allowing us to refine our search to include journal articles that feature key search terms in titles, abstracts or keywords, while still providing the most extensive results available (in comparison to, e.g., Scopus). Furthermore, this database enables the pre-selection of citation indices in the social sciences and humanities<sup>1</sup>, further approximating search parameters with our research intent.

For the search query, we developed a search string based on combinations of terms for the bioeconomy and for perceptions, respectively (Table 1). For the bioeconomy term, we only included the variations “bio-economy” and “bio-based economy”, in line with our focus on the bioeconomy concept itself. For synonyms of perceptions, we gradually added and tested terms that were used in the literature we found in preceding runs of the search query. Starting from the literature we found with the search term “perception”, we considered terms that were used in titles, abstracts or keywords to refer to synonyms or concepts related to stakeholder perceptions. We repeated this process until the additional terms did not produce any more new search results (as was the case for, e.g., “discourse”). The databank search was conducted on July 2<sup>nd</sup>, 2020, and retrieved 311 results, excluding duplicates.

Search terms for bioeconomy	Search terms for perceptions
“bioeconomy” “bio-economy” “bio-based economy”	“attitude” “definition” “frame” “imaginary” “narrative” “perception” “preference” “understanding” “vision”

**Table 1 Key search terms**

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<sup>1</sup> Social Sciences Citation Index (SSCI) --1900-present, Arts & Humanities Citation Index (A&HCI) --1975-present, and Emerging Sources Citation Index (ESCI) --2015-present.

These initial results were manually narrowed down in several further steps. First, we limited the results to English-language journal articles.<sup>2</sup> Second, we screened all remaining articles to verify that bioeconomy perceptions are the core object of research. Here, we made an important distinction between bioeconomy as a policy vision for a future model of sustainable natural resource management (see Section 2.1), as opposed to bioeconomy as the economy of life, as it is used mainly in the context of medical research [e.g. Brown, 2013, Lafuente-Funes, 2019]. While there is certainly a thematic overlap in the economization of nature, we chose to focus on the concept as promoted in the policy context (see Section 1). Third, we also excluded conceptual articles and policy reviews in order to focus on a review of empirical research on stakeholder perceptions. Nevertheless, these articles served as a valuable input for developing the analytical framework. These selection steps resulted in a data set of 108 publications as the basis for the analysis in this paper. A list of all articles is provided in Table A1.

### **2.3. Analytical framework**

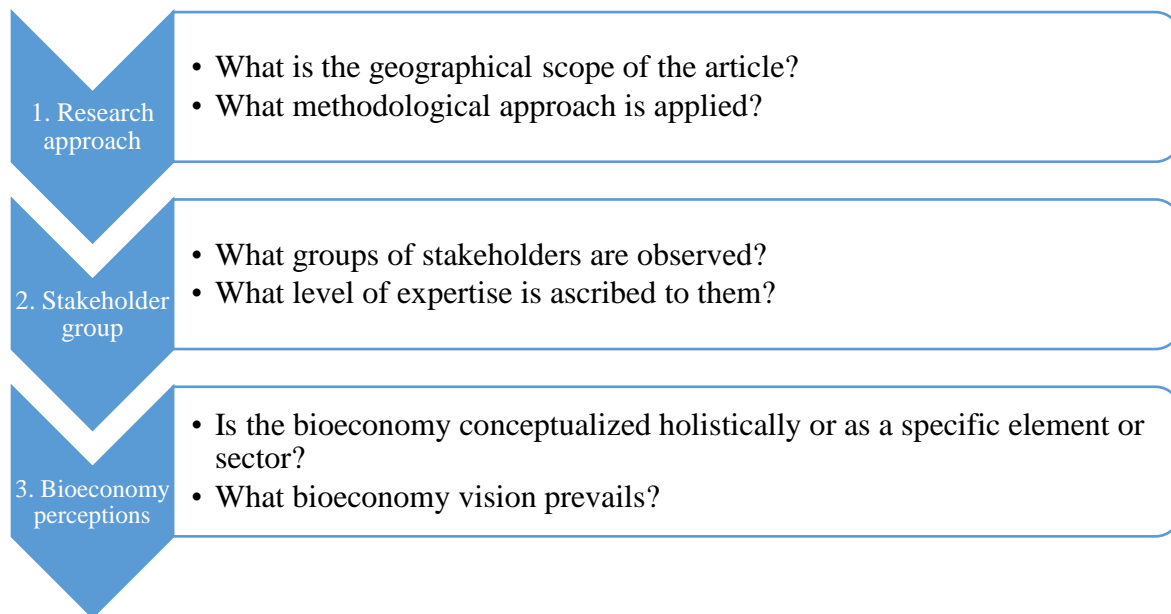
In order to provide a systematic literature review of empirical research on stakeholders' bioeconomy perceptions, we chose the established data analysis approach of developing and assigning codes to texts [Maxwell & Chmiel, 2014, Gibbs, 2014], which allows to identify and compare key characteristics and findings of the research works with a combination of qualitative and quantitative means. In this section, we first develop the research questions guiding the review and then translate them into the coding system and procedure.

For the content analysis, we first developed research questions about how stakeholders' perceptions of the bioeconomy are studied and what perceptions are found. This step was informed by the issues raised in the conceptual and policy review literature (section 2.1), specifically concerns about the concept's ambiguity and subsequently diverging design options, the context-dependence and scope of the bioeconomy, and a lack of participation by certain stakeholders.

The guiding analytical questions can be divided into three groups concerning research approach, investigated stakeholder group, and identified bioeconomy understanding, respectively (Figure 1). Within the framework of the literature review, we are interested in identifying the articles' methodological approach and geographical scope. Moreover, our analysis is concerned with what groups of stakeholders are observed. Given the observation of an expert-dominated bioeconomy debate [e.g. Dieken & Venghaus, 2020], the stakeholders' level of knowledge of and prior involvement in the bioeconomy are also of interest. Lastly, the literature highlights the challenge in both defining and delineating the bioeconomy. Thus, we seek to understand what the studies reveal about stakeholders' perceptions by first asking for the understanding in terms of the overarching interpretation of objectives and strategies. Since the dataset is very diverse, we supplemented this question by also considering assumptions about the design of the bioeconomy - specifically, on what level changes are envisioned and which part of the bioeconomy is discussed.

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<sup>2</sup> While this constitutes a limitation on the available research literature, it is a necessary choice given the authors' language proficiency, and a reasonable one since non-English articles constituted only 3.5% of the initial search results, most of which would have also been eliminated in the following selection step.



**Fig. 1 Groups of research questions guiding the literature review**

In order to operationalize these questions for the content analysis, we translated them into coding categories. For each category, we inductively developed individual codes based on the data set in order to specify differences while still allowing for aggregation, thus resulting in relatively broad and general codes (Table 2). The overview of conceptual and review articles aided us in identifying and differentiating characteristics of the text (Section 2.1). Only exception to the inductive approach is the category of bioeconomy understandings (9.), which we based on the bioeconomy visions as proposed by Bugge et al. [2016]. As indicated above, the ambiguity of the concept is a considerable research challenge, and thus, the codes for bioeconomy understanding needed to be, on the one hand, comprehensive and meaningful, and on the other hand, able to cover a set of extremely diverse research approaches and findings. Consequently, we adapted the conceptualization of three bioeconomy visions since it is broad enough to summarize the vast literature, while still enabling a differentiation along the major lines of thought regarding the bioeconomy's objectives and design. Moreover, this conceptualization is highly cited in the literature, also of our dataset [e.g. D'Amato et al., 2017, Hausknost et al., 2017, Priefer et al., 2017], and constitutes an important frame of reference for research on bioeconomy perceptions. Accordingly, we developed a coding system based on Bugge et al.'s visions, similar to our approach in preceding empirical research on the German bioeconomy [Dieken & Venghaus, 2020].

<p><i>Part 1: Research approach</i></p> <ol style="list-style-type: none"> <li>1. Methods <ol style="list-style-type: none"> <li>1.1. Quantitative</li> <li>1.2. Qualitative</li> <li>1.3. Mixed methods</li> <li>1.4. Unspecified/diverse</li> </ol> </li> <li>2. Sample size <ol style="list-style-type: none"> <li>2.1. [Number]</li> <li>2.2. Not applicable</li> </ol> </li> <li>3. Scope <ol style="list-style-type: none"> <li>3.1. International</li> </ol> </li> </ol>	<ol style="list-style-type: none"> <li>6. Level of expertise <ol style="list-style-type: none"> <li>6.1. High</li> <li>6.2. Low</li> <li>6.3. Mixed/unspecified</li> </ol> </li> </ol> <p><i>Part 3: Bioeconomy perceptions</i></p> <ol style="list-style-type: none"> <li>7. Bioeconomy focus <ol style="list-style-type: none"> <li>7.1. Holistic concept</li> <li>7.2. Underlying management principle</li> <li>7.3. Specific product/process/sector</li> </ol> </li> </ol>
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3.2. National 3.3. Regional 3.4. Local 3.5. Generic 4. Location 4.1. [Name]  <i>Part 2: Stakeholder group</i> 5. Type of stakeholder group 5.1. Citizens & consumers 5.2. Farmers & forest owners 5.3. Government & political actors 5.4. Industry & commerce 5.5. Media 5.6. Research 5.7. Social and environmental initiatives & NGOs	8. Bioeconomy elements 8.1. Governance & regulation 8.2. Biomass production 8.3. Utilization & biotech 8.4. Consumption 8.5. Ecological system 8.6. General overview  9. Bioeconomy understandings 9.1. Bio-technology 9.2. Bio-resource 9.3. Bio-ecology 9.4. Multiple/diverse
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**Table 2 Coding scheme**

In order to analyze the articles' research approaches, codes for methods, sample size, scope and location were developed. To allow for comparison, the sample size was determined as the minimum number of individual observations. For scope, we distinguished between whether the bioeconomy was discussed as local, regional, national or international development, or as a non-specific, generic phenomenon. If texts identified a specific country or place that was investigated, we coded this information as location.

Regarding the type of stakeholder group under investigation, codes largely follow the categories used most often in the articles. For the bioeconomy, the most prominent stakeholder groups are research, non-governmental organizations (NGOs), industry and public administration [e.g. Hausknost et al., 2017]. Based on these categorizations, we established seven stakeholder groups, characterized by their specific tasks in a bioeconomy transformation. Research encompasses stakeholders engaging in knowledge generation and technology development, farmers and forest owners provide biomass, industry and commerce utilize knowledge and biomass to create bio-based products, and citizens and consumers reflect the societal demand for bioeconomy products and the participation in bioeconomy governance. Government and political actors define the political framework of the bioeconomy, and social and environmental initiatives and NGOs the societal and ecological framework. Given that studies of citizens necessarily represent a subset of society, we additionally designated a dedicated code for media as an expression of public opinion.

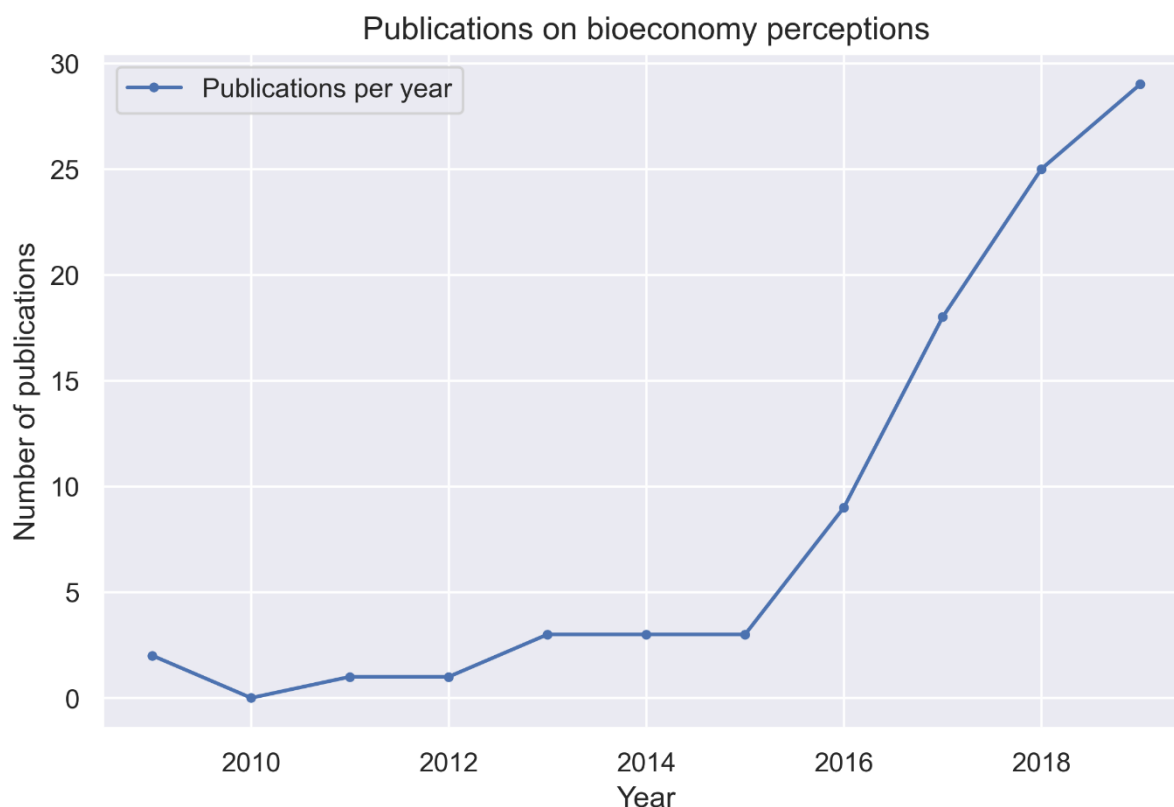
Since both group affiliation and level of expertise are not as clear-cut in reality as codes suggest, our categorization followed the individual studies' own characterization whenever possible. For the level of expertise, we distinguished between stakeholders who are highly knowledgeable of and involved in the bioeconomy (e.g. scientists working in life sciences), and stakeholders with little knowledge of or contact with the bioeconomy prior to the respective study (e.g. consumers). Also, a third code was developed to reflect studies that had a mixed group of experts and laymen.

Finally, we developed codes for analyzing bioeconomy perceptions in terms of three different aspects: the focus chosen (from individual product to grand policy concept), the sectors included (e.g., biomass production), and the bioeconomy understanding found. The codes for the three bioeconomy visions were assigned when articles' results on bioeconomy perceptions reflected one of the vision's core characteristics as defined by Bugge et al. [Bugge et al., 2016]). When different stakeholder perceptions were found, only the most dominant vision was coded for. When articles' results were mixed or not reflected in the bioeconomy visions, we coded them as *Multiple/diverse*. Regarding the focus on the bioeconomy, we differentiated between three levels of detail in the articles: 1) a holistic, broad perspective on the bioeconomy as a whole, 2) the bioeconomy as represented in a specific sector, process or even technology, and 3) a mid-level perspective on managerial paradigms, e.g., circularity. In terms of the bioeconomy elements, we observed that articles often single out a specific sector or policy field when discussing the bioeconomy, such as the stages of biomass production or industrial utilization. Thus, we differentiate between five elements of the bioeconomy, from the ecological system to the governance and regulation of the bioeconomy. Additionally, articles that do not focus on a specific element were identified as providing a general overview.

The analysis of the data set of research articles was conducted with a combination of qualitative and quantitative means. The articles were assigned codes according to the developed coding scheme, and the qualitatively gathered observations were then supplemented with a (semi-) quantitative summary of coding results (for the approach, see also [Venghaus & Hake, 2018]). In line with the inductive code development, code assignment followed the characterization and wording provided by the articles themselves where possible. Whenever the information provided was insufficient, articles were instead coded as mixed or unspecified. Per category and article, one code was assigned, with the exception of category 5, for which we allowed up to five separate codes per article in order to identify every stakeholder group included. This means that the results presented here are based mostly on articles covering more than one group of stakeholders - it is explicitly stated when results are exclusively based on articles that covered only one stakeholder group (see Section 3.1). Coding was conducted by the authors between July and October 2020. In order to check and provide for intercoder reliability [Mayring, 2004], the coding scheme was developed and refined together in regular meetings throughout the coding process. Coding results are presented in the following section.

### **3. Results of the systematic literature review**

Increasing policy concerns about the legitimacy, acceptance and potential development pathways of the bioeconomy are reflected in the exponentially growing amount of research dedicated to bioeconomy perceptions (Figure 2). We find articles on this topic to have been published since 2009. While journal publications remained relatively stable on the level of around 3 articles per year until 2015, the number has increased significantly since, to 29 in 2019. However, the trend seems to have slowed down more recently. For the current year at the time of writing, 2020, already 14 articles were found to have been published in the first six months. All in all, the analysis of bioeconomy perceptions is a notable and growing part of bioeconomy research.



**Fig. 2 Journal article publications on bioeconomy perceptions, per year**

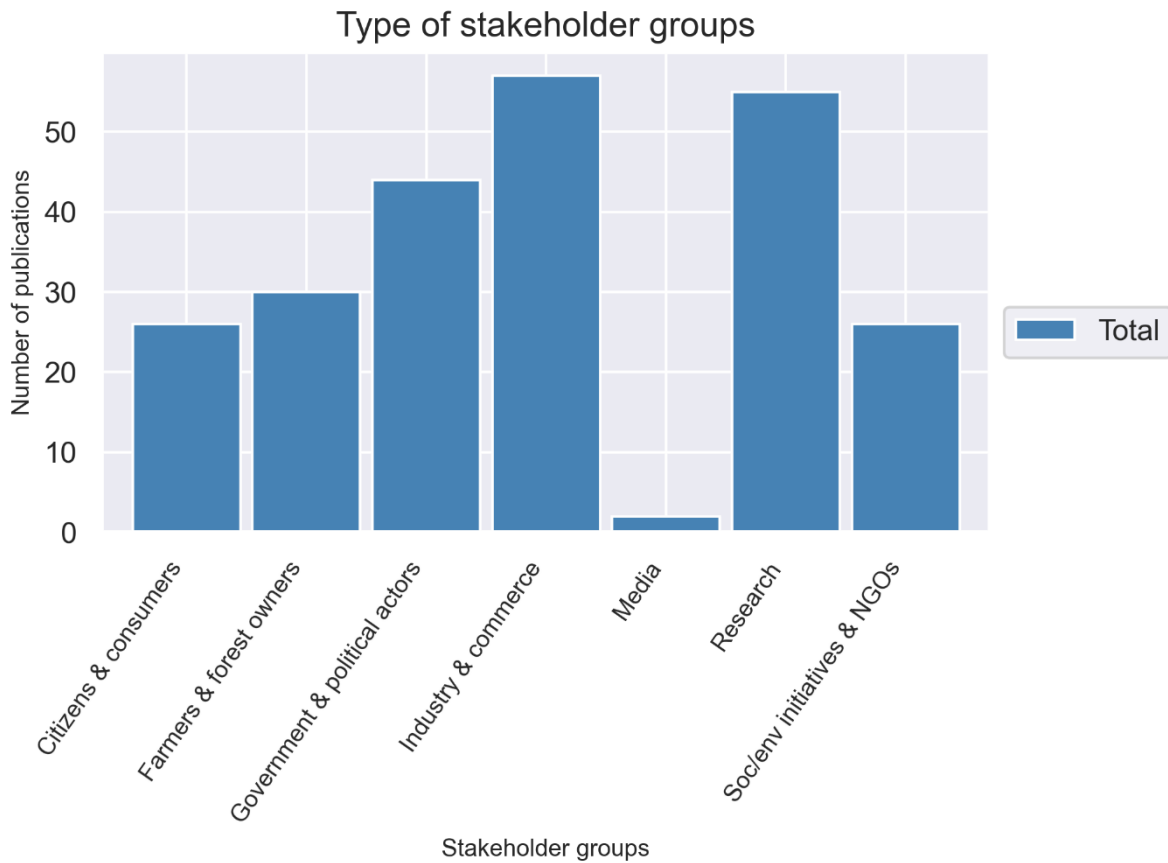
In sum, research articles on bioeconomy perceptions predominantly deal with a national bioeconomy in Europe, applying qualitative or mixed methods approaches to examine government, industry and research stakeholders, and ask general and regulatory questions about specific products and sectors. The geographical focus was especially pronounced, with 76 of 108 articles looking at European cases, whereas, e.g., only two Asian and three African cases were included. All in all, research on stakeholder perceptions of the bioeconomy focuses on a specific and limited set of actors and their perceptions of rather general aspects of the bioeconomy. At the same time, the findings for the category “bioeconomy perceptions” show that articles cover a variety of sectors and challenges, and perspectives are relatively equally distributed. Thus, a detailed analysis of the data in terms of differences of perceptions across stakeholder groups and methodological approaches is required.

### 3.1. Stakeholder perceptions - whose bioeconomy?

Research articles covered a range of stakeholders (Figure 3). However, the groups of *government & political actors*, *industry & commerce*, and *research* were investigated almost twice as often as *citizens & consumers*, *farmers & forest owners*, or stakeholders from *social and environmental initiatives & NGOs*. Also, only two articles were dedicated to the analysis of the *media*<sup>3</sup>, by Peltomaa [2018] and Ranacher et al. [2019]. This finding supports the observation that the bioeconomy is mostly discussed by the “golden triangle” of government, universities and industry [Mukhtarov et al., 2017]. The general, non-expert society is less often

<sup>3</sup> Thus, we will not explicitly compare results for the media with other stakeholder groups, but only include these data points in the figures for illustrative purposes.

analyzed. This imbalance of observed stakeholder groups is also noticeable from the share of stakeholders considered expert (61.1%) as opposed to layperson (10.1%), which largely coincides with *citizens & consumers*. Thus, most research on stakeholder perceptions is concerned with well-established expert groups.



**Fig. 3 Type of stakeholder groups investigated, absolute numbers**

However, the comparatively low number of research works on *farmers & forest owners* is surprising, since they are often considered the backbone of the bioeconomy, especially in Scandinavian countries, e.g. in the articles by Albrecht [2019] and Fischer et al. [2020]. Similarly, it has long been argued that the participation of the general public is key, but the number of articles concerned with *citizens & consumers* is even lower - especially since this category also includes articles dealing exclusively with society in its function as a market.

The lower prevalence of these stakeholder groups also relates to methodological differences in the studies. Overall, the majority of 65 articles (60.2%) investigates more than one group of stakeholders, often summarizing empirical observations into one common result. *Citizens & consumers* and *farmers & forest owners* are more often analyzed exclusively and quantitatively, while other groups are more often examined together and qualitatively, which increases their overall share - we discuss methodological choices in more depth in Section 3.2. Thus, a closer look is warranted at the 43 studies investigating exclusively one group of stakeholders (Table 3). In this case, the minor roles of the first two groups reverse, with *citizens & consumers* (34.9%) and *farmers & forest owners* (23.3%) constituting the two highest-scoring codes, resulting in almost the exact opposite of shares. This comparison demonstrates that when less-informed stakeholders from broader society are analyzed, this is mostly done separately from analyses of the dominant, expert stakeholder groups, e.g. in the form of focus group discussions

with citizens in Lynch et al. [2020]. A potential explanation is that official policy and stakeholder visions differ [Hausknost et al., 2017, Vainio et al., 2019], and thus researchers tend to focus on analyzing the (presumably) consistent position of a specific group or group constellation, either the dominant or an alternative perspective. This is also reflected in the conceptual literature, which generally distinguishes between two opposing interpretations of the bioeconomy, a technology-based and a socio-ecological one [Priefer et al., 2017, Stern et al., 2018]. However, the extent of these differences is difficult to ascertain when investigated separately. Thus, differences in results between studies of one or of several stakeholder groups are subsequently highlighted where relevant.

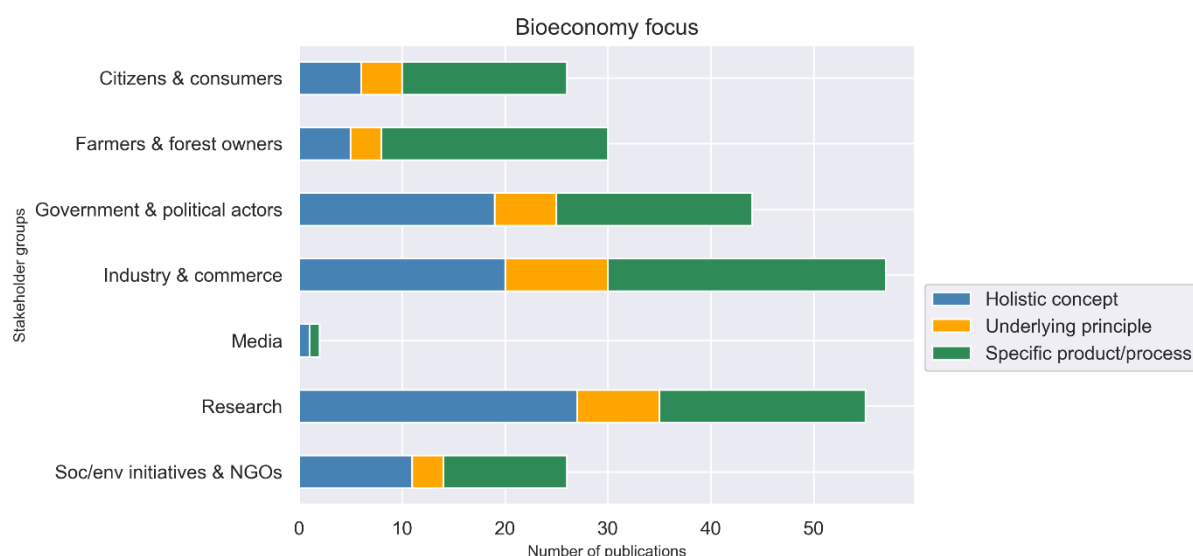
Observed Group	Freq.	Percent	Cum.
Citizens & consumers	15	32.61	32.61
Farmers & forest owners	10	21.74	54.35
Government & political actors	3	6.52	60.87
Industry & commerce	7	15.22	76.09
Media	2	4.35	80.43
Research	9	19.57	100.00
Total	46	100.00	

**Table 3 Type of stakeholder groups investigated, number of articles with sole focus**

Against this background, we compared bioeconomy perceptions as determined in the research articles across stakeholder groups. Specifically, we compared the results for differences in the chosen focus and sectors, as well as in the identified understandings and prevailing challenges and opportunities.

In terms of the focus on the bioeconomy, most articles deal either with it as a *holistic concept* (33.3%) or with a *specific product, process or sector* (51.9%), referencing the context of the bioeconomy rather shortly. Interestingly, we find only few texts addressing it as an *underlying management principle* (14.8%), which could be attributed to a general lack of links between policy strategies and actual legislation [Wydra, 2020]. When comparing the results for each stakeholder group (Figure 4), we found this observation to remain valid overall, but there are differences roughly reflecting the rift between two clusters of stakeholder groups, as identified before. For *citizens & consumers*, *farmers & forest owners* and *industry & commerce* stakeholders, articles primarily focus on *specific products*. For stakeholders from *research* and *government & political actors*, in contrast, the focus rests on the *holistic concept*. *Social and environmental initiatives & NGOs* are found to have a more equally distributed focus - this can be a result of this group being relatively heterogeneous. While the result of articles on *industry & commerce* stakeholders having a product-oriented focus is expected, it is surprising that *farmers & forest owners* and *citizens & consumers* are rarely asked about the bioeconomy as a

broad concept. It appears that research on their perceptions is limited to the acceptance and adoption of specific products and processes, i.e. consumer acceptance, as is the primary focus, e.g., in the articles by Stern et al. [2018] and Thomas et al. [2018]. Moreover, it is surprising that researchers' perceptions are predominantly investigated in terms of the bioeconomy as a holistic concept, even though in the articles, this group of stakeholders is largely identified to be conducting the research and development of specific biotechnologies, e.g. by Giurca [2020] and Laibach et al. [2019]. Thus, the results on the bioeconomy focus underline the dominance of certain expert groups in bioeconomy research and policy.

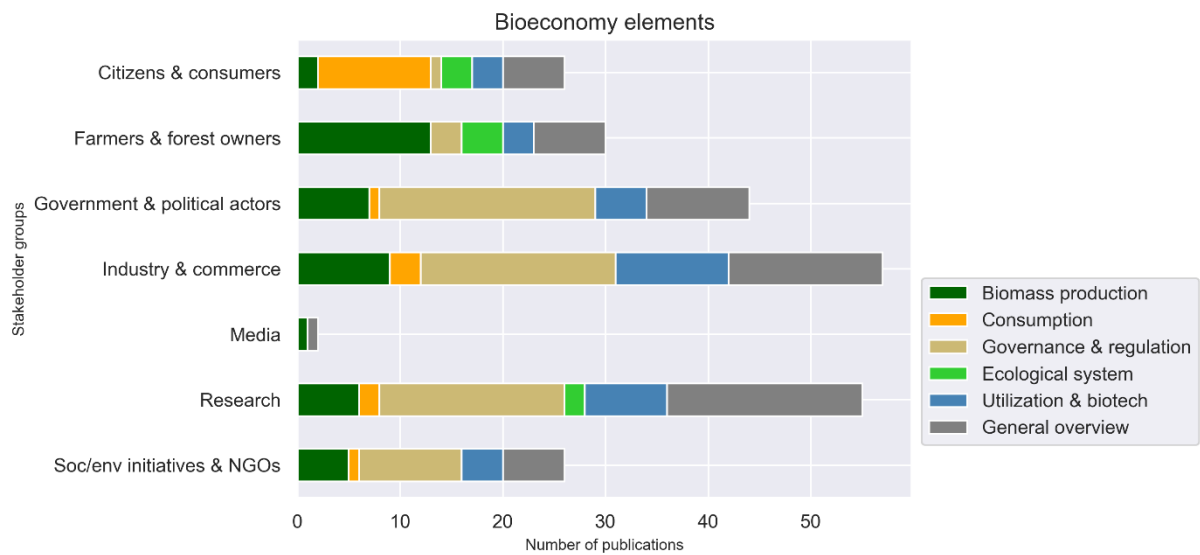


**Fig. 4 Bioeconomy focus of articles according to stakeholder group, absolute numbers**

Given these differences in perspective, we questioned whether stakeholder perceptions also differ in terms of content. Thus, we compared elements of the bioeconomy that were regarded in the literature. Overall, research on perceptions is distributed relatively evenly across different bioeconomy elements. The most prevalent elements are *governance & regulation* (25.9%), *biomass production* (17.6%), and *utilization & biotechnology* (15.7%), with fewer works on *consumption* (10.1%), the *ecological system* (4.6%), as well as a high share of works on a *general overview* (25.9%). These results reinforce the observations of the preceding step, namely that articles generally focus on perceptions of the bioeconomy as a whole, or on specific products, originating from the biomass production or utilization stages of the bioeconomy.

Comparing results across stakeholder groups (Figure 5), most of the identified differences were expected. *Farmers & forest owners* are primarily investigated in terms of *biomass production*, *government & political actors* and *social and environmental initiatives & NGOs* in terms of *governance*, and *citizens & consumers* in terms of *consumption*. This last result also supports the assumption discussed earlier, namely that the general public is surveyed more often about consumption choices than broader questions regarding the bioeconomy or its governance. Other results, however, are less expected, especially that perceptions addressing the ecological system are exclusively analyzed for *citizens & consumers*, *farmers & forest owners* and *research* actors [in Atwell et al., 2009, Matthies et al., 2018, Nankya et al., 2017, Ranacher et al., 2017, Thomas et al., 2018], whereas not at all for *social and environmental initiatives & NGOs*. This may be explained by the fact that this last group is not the central focus of most articles and was indeed only examined in conjunction with at least two further stakeholder groups, so that the focus of these articles is on other aspects. Moreover, we can further support the observation that works

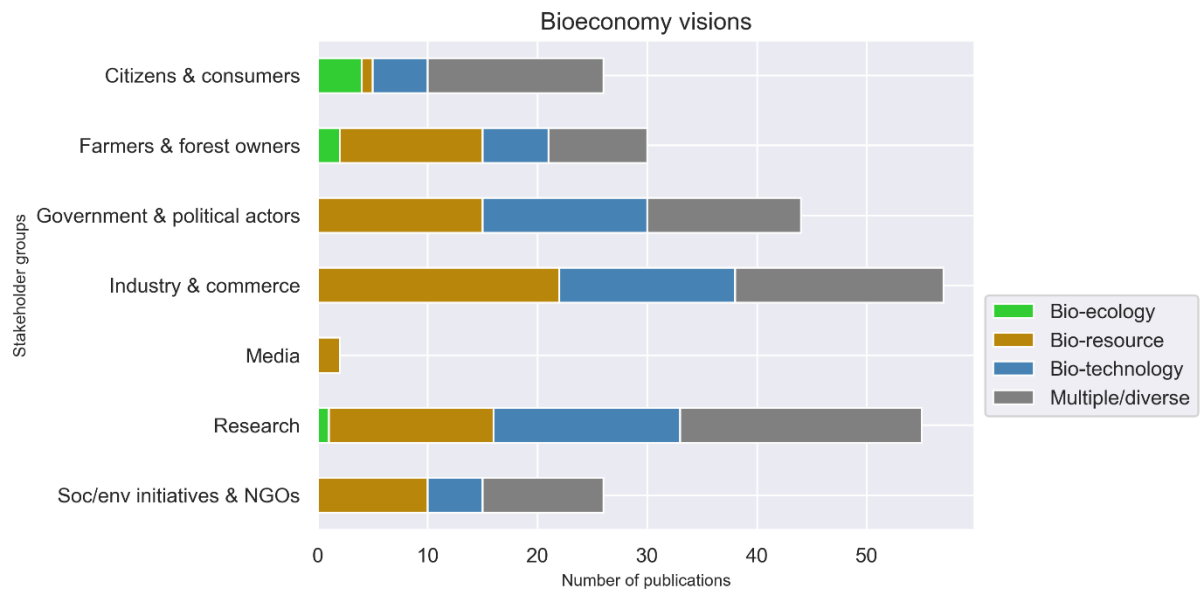
on broader perceptions of the bioeconomy predominantly focus on the stakeholder groups *research, industry & commerce* and *government & political actors*.



**Fig. 5 Bioeconomy elements focused on in articles according to stakeholder group, absolute numbers**

The content-wise perception differences between stakeholder groups are more pronounced when comparing the bioeconomy understandings. Overall, 40.7% of all articles were not uniquely identifiable in terms of the underlying bioeconomy vision, as defined by the conceptualization of Bugge et al. [2016]. There are several reasons for this, as explained in the description of our coding process (section 2.3). Additionally, the analysis revealed that more than half of all articles focus on a specific product or process, so in many cases claims in hindsight on the overall bioeconomy understanding were not viable. This adds to a high share of articles within which *multiple/diverse* understandings were found.

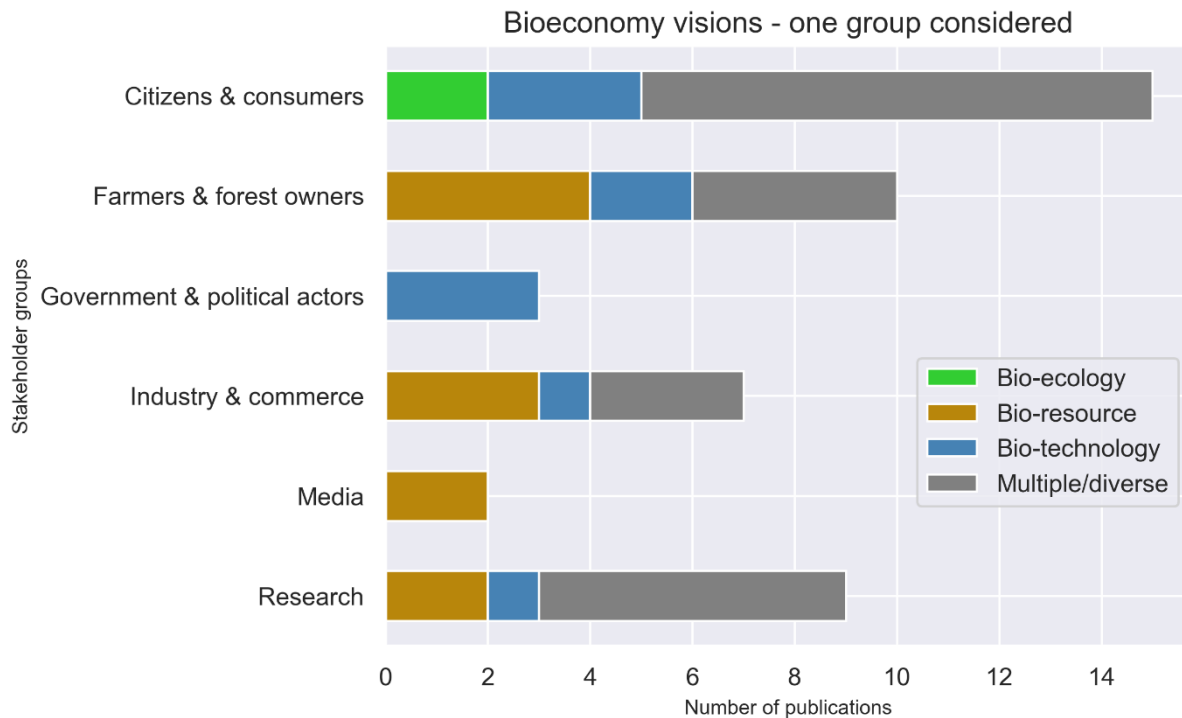
For the bioeconomy visions, results show an almost equal split between the *bio-technology* (26.9%) and *bio-resource visions* (28.7%). In turn, we only identified the results of four articles as reflecting the *bio-ecology vision*, namely works by Gheorghe et al. [2019], Ranacher et al. [2019], Stern et al. [2018] and Thomas et al. [2018]. These shares demonstrate the extent to which bioeconomy perceptions are dominated by a technology-based perspective [Stern et al., 2018, Dieken & Venghaus, 2020], with the presence of a resource-based understanding growing in importance more recently [Peltomaa, 2018]. Since we already found a strong dominance of certain groups of stakeholders, we also analyzed whether the strong focus on technology and resources can be attributed to them (Figure 6).



**Fig. 6 Bioeconomy visions identified in articles according to stakeholder group, absolute numbers**

First, we found the diversity of visions to be the strongest for *citizens & consumers*, for which 61.5% of the results were identified as containing multiple visions - for the other stakeholder groups, 30-42% of results were categorized as such. Moreover, *citizens & consumers* were the only group identified to support the *bio-ecology* vision to a substantial degree. This vision was found for the groups of *research* and *farmers & forest owners* as well, however, in this case as a side issue. Furthermore, the *bio-resource* vision was most often identified among *farmers & forest owners*, *industry & commerce* actors and *social and environmental initiatives & NGOs*. This is related to these groups' thematic focus on issues of biomass production. For *industry & commerce*, this relatively significant tendency towards a *bio-resource* (38.6%) rather than a *bio-technology* vision (28.1%) can be explained by the considerable presence of forest-related industries, e.g. in articles by Bullock et al. [2020] and Näyhä [2019]. In turn, the *bio-technology* vision was mainly found for *citizens & consumers* (19.2%) and *research* (30.9%). *Government & political actors* are found to be evenly split between both visions (34.1% respectively). These findings support literature on the strong dominance of a bioeconomy narrative driven by political, industry and research actors. Nonetheless, two aspects stand out. First, stakeholders' bioeconomy perceptions appear to be found evenly split between *bio-technology* and *bio-resource* visions, partially contradicting the assumption of an overly dominating technology-based understanding. Also, the seemingly elitist *bio-technology* vision is found to have strong support among other societal actors, although *citizens & consumers* especially were identified as representing the marginal *bio-ecology* vision and *diverse understandings* as well.

Since most articles investigated more than one stakeholder group, the aggregated results presented here could conceal differences for stakeholder groups which were often analyzed together, e.g. *industry & commerce* and *government & political actors*. Thus, we also compared bioeconomy visions across only the 43 articles that covered exactly one stakeholder group (Figure 7).



**Fig. 7 Bioeconomy visions identified in articles covering only one stakeholder group, according to group**

Compared to articles covering more than one stakeholder group, the conclusions of these articles tend more towards the *bio-resource* vision for *industry & commerce* as well as *research*. *Government & political actors*, in contrast, are exclusively examined in only three research articles, namely by Ciervo [2016], Kleinschmit et al. [2017] and Ramcilovic-Suominen and Pölzl [2018], which all show a prevailing *bio-technology* vision. This further supports two of our initial assumptions. Firstly, that the technology-based bioeconomy understanding is driven by mainstream policy discourse. And, secondly, that the *industry & commerce* group is characterized by many biomass-related industries who are more likely to take a resource-based perspective. Apart from this, the overall picture remains similar: Most articles do not identify a clearly prevailing vision (*multiple/diverse*), while the remaining articles are split between *bio-resource* and *bio-technology* visions with a tendency towards *bio-resource* as the prevailing vision. The only exception is, again, the group of *citizens & consumers*, as articles examining these are split between *bio-ecology* and *bio-technology* visions, with only a few articles focusing on the *bio-resource* vision. Thus, the results for articles on a single stakeholder group vs. multiple groups lead to a similar conclusion: a large share of diverse visions and a clear dominance of a technology- and resource-based understanding.

### 3.2. Methodological choices - which bioeconomy?

The comparison of stakeholder-specific bioeconomy perceptions brought forth questions about the methodological choices in literature. These seem especially interesting, since research on bioeconomy perceptions is so diverse and fragmented. The comparison of methodology allows to take account of how the issue at hand has and has not yet been studied, and to discuss the implications for the respective findings. We found that research articles predominantly employ *qualitative* (56.5%) or *mixed methods* (23.1%) approaches, whereas only a minority of 20.4%

used a *quantitative* approach. Median sample size was 23 for qualitative studies and 218.5 for the fewer quantitative studies. Overall, research mostly targeted explorative, in-depth analyses of specific stakeholder perceptions for a small number of cases, rather than representative surveys of a broad population. This highlights the state of research on bioeconomy perceptions. While the term bioeconomy has been used in political documents for up to 20 years now, bioeconomy research especially in the social sciences is still in its infancy where explorative and qualitative works often prevail. Such qualitative works allow examining views on the bioeconomy and related concepts even for individuals who are not very familiar with the concept, while the downside is a lack of comparability and explanatory power.

Besides the sample size, the difference in methodology is also related to the number and type of stakeholders examined. While the majority of quantitative studies (68.2%) focus on a single group, this is the case roughly half as often for qualitative (36.1%) and mixed methods (36.0%) studies. In addition, certain stakeholder groups tend to be analyzed in combination. Table 4 shows the pairwise correlation coefficients between dummy variables indicating the presence of each group in the respective article's analysis. *Citizens & consumers*, and to some extent *farmers & forest owners*, are more often analyzed on their own, as we already noted also in the preceding section (Section 3.1.). In contrast, the groups of *government & political actors*, *industry & commerce*, *research*, and *social and environmental initiatives & NGOs* are frequently analyzed jointly. This is suggested by the positive correlation coefficients for appearances of these groups in the research articles (Table 4). For example, the negative correlation between citizens & consumers and government & political actors indicates that when one of these groups is analyzed the other is less often analyzed by the same article, while the positive correlation between government & political actors (3) and industry and commerce (4) indicates that the other group is present relatively more often in the same article if one of them is analyzed. This means that the selection of stakeholder groups reinforces the assumption of a coherent coalition between government and industry (and research) by analyzing them as one group with common perceptions, as opposed to the separately investigated civil society. Moreover, in analyzing specific groups only in certain combinations or with certain approaches, stakeholder perceptions are difficult to differentiate or relate to each other. Thus, potential differences or commonalities of perceptions across or within stakeholder groups are blurred. The approach used here, which itself operates on a relatively general level, is already able to question the assumption of the group of citizens as an outsider to the dominant bioeconomy discourse by relating the sparse existing findings to each other. This further highlights the critical impact of methodology in identifying bioeconomy perceptions.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Citizens & consumers	1.000					
(2) Farmers & forest owners	-0.059	1.000				
(3) Government & political actors	-0.379	-0.136	1.000			
(4) Industry & commerce	-0.292	-0.076	0.407	1.000		

(5) Research	-0.314	-0.094	0.324	0.259	1.000	
(6) Social and environmental initiatives & NGOs	-0.266	0.038	0.503	0.446	0.379	1.000

**Table 4 Correlation of the type of stakeholder groups investigated jointly in the articles**

Six dummy variables were coded as 1 for the presence or 0 for the absence of the respective type of stakeholder-group in each article. Pairwise correlation coefficients between dummy variables for each stakeholder group are shown.

#### 4. Discussion: multitudes of bioeconomies?

Overall, the literature review showed articles to investigate a wide variety of aspects and stakeholders of the bioeconomy. Most attention was given to political, research and industry actors, who were often analyzed jointly. This substantiates concerns about unequal participation of stakeholders in the bioeconomy debate, and highlights a lack of research on actors from civil society and – surprisingly, – biomass producers.

The dominant stakeholder groups are found in equal support of the bio-technology and bio-resource understandings, which is largely echoed by the other stakeholder groups, confirming this interpretation as the prevailing bioeconomy vision. However, our framework was able to capture some notable deviations. Taking a closer look into research on one single group of stakeholders, we find that the bio-technology vision can be mainly attributed to political actors, and the bio-resource vision to industry actors. This suggests a need for more differentiation within the “golden triangle” than is currently provided by literature analyzing them jointly in terms of common perceptions, and highlights the impact of methodological choices.

Moreover, the literature reveals a considerable support for a technology-based bioeconomy understanding in the group of citizens and consumers. This indicates a different potential for coalitions than the prevailing observation of a techno-centric “golden triangle” as opposed to broader society as a marginalized, alternative position. At the same time, the literature shows notable support among the same group for the bio-ecology vision, a vision which is only marginal in findings on other stakeholders. Taken together with a large share of empirical findings which could not be assigned to a preconceived vision, either in the original research or the review, we find that perceptions by citizens and consumers are the least consistent and most diverse, leaving a lot of open questions about where this large group stands in regard to the bioeconomy. Simultaneously, the joint analysis of groups and the different methodological choices for certain groups raise the question of what differences and commonalities might be blurred.

Particularly noteworthy in this regard is the observed lack of ecological and social concerns, and an underrepresentation of stakeholder groups associated with such concerns. This gap is aggravated by the lack of research on developing and emerging countries. On the one hand, this neglects the global trade dimension of biomass and biotechnology, especially for India (considered in one out of 108 articles, [Salter et al., 2016]) and China (in two, [Salter et al., 2016, Pätäri et al., 2017]) as well as Brazil (in none). On the other hand, this conceals issues of global justice in the sense of negative ecological and social implications of biomass production

and consumption, which might have been outsourced to developing countries. For example, we found only three studies concerned with African case studies, specifically in the countries of Kenya, Madagascar and Uganda [Hunsberger, 2016, Neimark, 2016, Nankya et al., 2017].

In sum, these findings undermine the bioeconomy concept's claim to contribute to sustainable development. They reveal a disconnect between the bioeconomy's conceptualization as a transformation pathway towards sustainability on the one hand, and stakeholders' perceptions on the other, which primarily revolve around national economic growth generated by biotechnology and biomass utilization (at least as researched up to this point). This highlights the need for closely monitoring the bioeconomy's sustainability impacts and stakeholders' perceptions thereof.

In addition, the findings of our literature review provide some suggestions for further research. The central challenge which characterized the articles under review here and our research approach, is that of delineating and differentiating understandings of the bioeconomy. For this literature review, this finding concerns the methodological approach of analyzing bioeconomy visions with a predefined conceptualization. Such a conceptualization is necessarily limited in capturing differences identified in the field, let alone by research under different conceptual frameworks. For the purpose of the review, we approached this challenge by supplementing the code category based on Bugge et al. [2016] with two other code categories for the differentiation of perceptions, bioeconomy elements and bioeconomy focus. Results overall support the findings of bio-technology and bio-resource visions dominating stakeholder perceptions. This demonstrates the suitability of Bugge et al.'s approach for approximating and comprehensively comparing literature on bioeconomy perceptions. However, further work is needed to relate findings with respect to specific products and processes (e.g. the support for a specific technology or cultivation method) to overall principles and the general concept of the bioeconomy. Extending the existing framework of bioeconomy visions in such a way would help to advance and unify the body of literature on stakeholder perceptions.

For studies on bioeconomy perceptions in general, the finding of a large share of unspecified bioeconomy visions suggests that stakeholders' understanding and reasoning regarding the bioeconomy differ from, or at least cut across, the conceptual frameworks developed by policy and research communities – an aspect supporting the observation that the bioeconomy discourse is strongly expert-driven. Given these conceptual and methodological challenges, more research taking an exploratory, inductive approach to analyzing visions is needed, which further details the differences between and within specific stakeholder groups not captured by current concepts. For example, narrative analysis provides a useful frame for identifying stakeholders' distinct argumentation for the bioeconomy beyond generalized themes as analyzed here for the purpose of the review.

The identification of stakeholder groups constituted a similar research challenge. Stakeholders often play more than one role, and this role can also change depending on the questions asked. For example, especially in rural contexts a stakeholder might cultivate land, which would identify him/her as a farmer, but also fill the position of the municipality's mayor, which would characterize him/her as a political actor. Moreover, some stakeholders are at the intersection of group types, e.g., ministerial researchers or farmers operating a bio-refinery. Thus, in some cases bioeconomy stakeholders are difficult to categorize unambiguously. Furthermore, the characteristics within a (seemingly) clearly defined group can differ considerably, e.g., Kenyan vs. German farmers. In this work, we chose to assign relatively broad stakeholder categories in

order to allow for identifying trends, instead of assigning more specific but unsuitably many categories.

Against the background of challenges in defining bioeconomy understandings and stakeholder groups, the methodological choices in studies of stakeholder perceptions are of particular interest. The preference for small-scale qualitative research highlights the difficulties in analyzing an elusive concept such as the bioeconomy, which is largely unknown to the broad public as a term and especially regarding its objectives [Kiresiewa et al., 2019, Hempel et al., 2019]. At the same time, qualitative approaches tended to be employed for the main players of the bioeconomy debate. This is likely connected to the respective size of the stakeholder groups, with citizens providing the largest available sample size, but also shows that the arguments of the dominant stakeholders are explored in more depth. Thus, more large-scale representative research is warranted, e.g. public surveys on national bioeconomy strategies' definitions and objectives could identify the key issues which are unknown to the public or on which perceptions conflict. In this regard, the lack of media analyses is curious, since it provides an excellent insight into issues of public debate [Ranacher et al., 2019, Puttkammer & Grethe, 2015]<sup>4</sup>.

The overall minor role of citizens and societal actors in research on bioeconomy perceptions can be partly explained by a similar absence of these groups from bioeconomy governance processes [Stern et al., 2018], which in turn can impede their identification by researchers. Moreover, research on citizens' perceptions is challenged by this group's considerable lack of knowledge of the bioeconomy, which has been identified as a threat to the acceptance of and participation in a bioeconomy transformation [Wydra, 2020]. Against this background, the review demonstrates a worrisome lack of engagement with the public.

Thus, while we find a large and growing catalog of research on bioeconomy perceptions, we also arrive at a lot of open questions. Despite the vast diversity of research approaches and the bioeconomy concept's ambiguity and complexity, the coding of three distinct visions allowed us to categorize individualized and context-specific perceptions into overarching major lines of argumentation, providing a broad overview of the current state of research findings. In the dynamic context of the bioeconomy, further research on stakeholder perceptions is critical, both in terms of more in-depth and more representative works, especially beyond Europe.

## 5. Conclusion

The bioeconomy constitutes a popular policy and research concept with the potential to contribute to sustainable development. This concept suggests substantial changes to resource governance, which go hand and hand with social change processes [Priefer & Meyer, 2019, Mukhtarov et al., 2017, Peltomaa, 2018, Hausknost et al., 2017]. Against this background, research on stakeholders' perceptions is valuable for understanding challenges to the legitimacy and acceptance of a bioeconomy transformation, and for analyzing in which regard stakeholders influence these change processes. Thus, we conducted a systematic literature review of research on bioeconomy perceptions in order to provide a comprehensive overview on the current state of research and streamline further research. To this aim, we based our review on the

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<sup>4</sup> We contributed a media analysis for the case of Germany later in 2020, outside of the time frame analyzed here [Dieken & Venghaus, 2020].

development and application of a coding scheme covering the methodological approach, the investigated stakeholder groups and the identified bioeconomy perceptions.

This review found an overall strong tendency towards case-specific and in-depth research on a specific and limited set of stakeholders and their perceptions of rather general aspects of the bioeconomy. The existing research focusing on the perception of industry, political and research stakeholders is dominated by a technology-based and resource-based understanding of the concept. We identified a noticeable lack with respect to the ecological dimension of the bioeconomy in stakeholder perceptions and a concerning lack of public involvement, which challenges the bioeconomy concept's claim to contribute to sustainable development. Thus, further research should strengthen the integration of respective stakeholder groups beyond specific topics of consumption to avoid a potential backlash in future implementation aspirations. Moreover, subsequent research could investigate the question of why a concept introduced as an effort to increase sustainability lacks research in terms of the ecological dimension – especially for those stakeholder groups that are shaping the overall transformation process. Finally, the diverse, fragmented and explorative nature of the literature under review here suggests that both more in-depth and more representative works are needed in order to further investigate potential differences between stakeholder perceptions, while ruling out differences attributable to methodological choices.

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## Appendix

### Bioeconomy perceptions - list of publications

Publication Year	Authors	Article Title
2020	Biber-Freudenberger, L; Ergeneman, C; Forster, JJ; Dietz, T; Borner, J	Bioeconomy futures: Expectation patterns of scientists and practitioners on the sustainability of bio-based transformation
2020	Borge, L; Broring, S	What affects technology transfer in emerging knowledge areas? A multi-stakeholder concept mapping study in the bioeconomy
2020	Bowditch, E; Santopuoli, G; Binder, F; del Rio, M; La Porta, N; Kluvankova, T; Lesinski, J; Motta, R; Pach, M; Panzacchi, P; Pretzsch, H; Temperli, C; Tonon, G; Smith, M; Velikova, V; Weatherall, A; Tognetti, R	What is Climate-Smart Forestry? A definition from a multinational collaborative process focused on mountain regions of Europe
2020	Broad, GM	Making Meat, Better: The Metaphors of Plant-Based and Cell-Based Meat Innovation
2020	Bullock, RCL; Zurba, M; Parkins, JR; Skudra, M	Open for bioenergy business? Perspectives from Indigenous business leaders on biomass development potential in Canada
2020	Donner, M; Gohier, R; de Vries, H	A new circular business model typology for creating value from agro-waste
2020	Fischer, K; Stenius, T; Holmgren, S	Swedish Forests in the Bioeconomy: Stories from the National Forest Program
2020	Giurca, A	Unpacking the network discourse: Actors and storylines in Germany's wood-based bioeconomy
2020	Hunt, KP; Wald, DM	The Role of Scientific Source Credibility and Goodwill in Public Skepticism Toward GM Foods
2020	Korhonen, J; Koskivaara, A; Toppinen, A	Riding a Trojan horse? Future pathways of the fiber-based packaging industry in the bioeconomy
2020	Ladu, L; Imbert, E; Quitzow, R; Morone, P	The role of the policy mix in the transition toward a circular forest bioeconomy
2020	Nayha, A	Finnish forest-based companies in transition to the circular bioeconomy - drivers, organizational resources and innovations
2020	Sijtsema, SJ; Snoek, HM; van Haaster-de Winter, MA; Dagevos, H	Let's Talk about Circular Economy: A Qualitative Exploration of Consumer Perceptions
2020	Temmes, A; Peck, P	Do forest biorefineries fit with working principles of a circular bioeconomy? A case of Finnish and Swedish initiatives
2019	Albrecht, M	(Re-)producing bioassemblages: positionalities of regional bioeconomy development in Finland
2019	Baublyte, G; Korhonen, J; D'Amato, D; Toppinen, A	Being one of the boys: perspectives from female forest industry leaders on gender diversity and the future of Nordic forest-based bioeconomy
2019	Bezama, A; Ingrao, C; O'Keeffe, S; Thran, D	Resources, Collaborators, and Neighbors: The Three-Pronged Challenge in the Implementation of Bioeconomy Regions
2019	Bratucu, G; Constantin, CP; Chitu, IB; Gradinaru, E; Dovleac, L	Approaching the Bioeconomy in Terms of Increasing the Energy Efficiency of Households in Romania
2019	D'Adamo, I; Falcone, PM; Gastaldi, M; Morone, P	A Social Analysis of the Olive Oil Sector: The Role of Family Business
2019	D'Amato, D; Droste, N; Winkler, KJ; Toppinen, A	Thinking green, circular or bio: Eliciting researchers' perspectives on a sustainable economy with Q method
2019	Devaney, L; Iles, A	Scales of progress, power and potential in the US bioeconomy

- 2019 Gheorghe, IR; Purcarea, VL; Gheorghe, CM  
 2019 Gillich, C; Narjes, M; Krimly, T; Lippert, C  
 2019 Golowko, N; Marquardt, K; Budz, S; Foerster-Metz, US  
 2019 Hernandez, VL; Schanz, H  
 2019 Huber, P; Hujala, T; Kurttila, M; Wolfslehner, B; Vacik, H  
 2019 Hurmekoski, E; Lovric, M; Lovric, N; Hetemaki, L; Winkel, G  
 2019 Laibach, N; Borner, J; Broring, S  
 2019 Morrison, M  
 2019 Nayha, A  
 2019 Olschewski, R; Tzanova, P; Thees, O; Polosek, P  
 2019 Pasnicu, D; Ghenta, M; Matei, A  
 2019 Priefer, C; Meyer, R  
 2019 Ranacher, L; Ludvig, A; Schwarzbauer, P  
 2019 Sanz-Hernandez, A; Sanagustin-Fons, MV; Lopez-Rodriguez, ME  
 2019 Takala, T; Tikkanen, J; Haapala, A; Pitkanen, S; Torssonen, P; Valkeavirta, R; Poykko, T  
 2019 Toppinen, A; Sauru, M; Patari, S; Lahtinen, K; Tuppur, A  
 2019 Vainio, A; Ovaska, U; Varho, V  
 2019 Vita, G; Lundstrom, JR; Hertwich, EG; Quist, J; Ivanova, D; Stadler, K; Wood, R  
 2019 Vivien, FD; Nieddu, M; Befort, N; Debref, R; Giampietro, M  
 2019 Wensing, J; Carraresi, L; Broring, S  
 2019 Wesseler, J; Politiek, H; Zilberman, D  
 2019 Zeug, W; Bezama, A; Moesenfechtel, U; Jahkel, A; Thran, D
- Pro-Environmental Behavior and Bioeconomy: Reflections on Single-Bottled Water Consumption  
 Combining choice modeling estimates and stochastic simulations to assess the potential of new crops-The case of lignocellulosic perennials in Southwestern Germany  
 German Students' Perception of Bioeconomy – An Exploratory Study  
 Agency in actor networks: Who is governing transitions towards a bioeconomy? The case of Colombia  
 Application of multi criteria analysis methods for a participatory assessment of non-wood forest products in two European case studies  
 Frontiers of the forest-based bioeconomy - A European Delphi study  
 Exploring the future of the bioeconomy: An expert-based scoping study examining key enabling technology fields with potential to foster the transition toward a bio-based economy  
 Making Cells Worthwhile: Calculations of Value in a European Consortium for Induced Pluripotent Stem Cell Banking  
 Transition in the Finnish forest-based sector: Company perspectives on the bioeconomy, circular economy and sustainability  
 How does wood mobilization depend on marketing decisions? A country comparison based on choice experiments  
 Transition to Bioeconomy: Perceptions and Behaviors in Central and Eastern Europe  
 One Concept, Many Opinions: How Scientists in Germany Think About the Concept of Bioeconomy  
 Depicting the peril and not the potential of forests for a biobased economy? A qualitative content analysis on online news media coverage in German language articles  
 A transition to an innovative and inclusive bioeconomy in Aragon, Spain  
 Shaping the concept of bioeconomy in participatory projects - An example from the post-graduate education in Finland  
 Internal and external factors of competitiveness shaping the future of wooden multistory construction in Finland and Sweden  
 Not so sustainable? Images of bioeconomy by future environmental professionals and citizens  
 The Environmental Impact of Green Consumption and Sufficiency Lifestyles Scenarios in Europe: Connecting Local Sustainability Visions to Global Consequences  
 The Hijacking of the Bioeconomy  
 Do pro-environmental values, beliefs and norms drive farmers' interest in novel practices fostering the Bioeconomy?  
 The Economics of Regulating New Plant Breeding Technologies-Implications for the Bioeconomy Illustrated by a Survey Among Dutch Plant Breeders  
 Stakeholders' Interests and Perceptions of Bioeconomy Monitoring Using a Sustainable

2018	Baudry, G	Development Goal Framework How the cap limit for food-crop-based biofuels may affect France's stakeholders by 2030? A range-based multi-actor multi-criteria analysis
2018	Bauer, F	Narratives of biorefinery innovation for the bioeconomy: Conflict, consensus or confusion?
2018	Bennich, T; Belyazid, S; Kopainsky, B; Diemer, A	Understanding the Transition to a Bio-Based Economy: Exploring Dynamics Linked to the Agricultural Sector in Sweden
2018	Berg, S; Cloutier, LM; Broring, S	Collective stakeholder representations and perceptions of drivers of novel biomass-based value chains
2018	Bosman, R; Loorbach, D; Rotmans, J; van Raak, R	Carbon Lock-Out: Leading the Fossil Port of Rotterdam into Transition
2018	Falcone, PM; Imbert, E	Social Life Cycle Approach as a Tool for Promoting the Market Uptake of Bio-Based Products from a Consumer Perspective
2018	Gardan, DA; Andronie, M; Gardan, IP; Andronie, IE; Iatagan, M; Hurloiu, I	Bioeconomy Development and Using of Intellectual Capital for the Creation of Competitive Advantages by SMEs in the Field of Biotechnology
2018	Giurca, A; Metz, T	A social network analysis of Germany's wood-based bioeconomy: Social capital and shared beliefs
2018	Gowan, CH; Kar, SP; Townsend, PA	Assessing Washington State Landowners' Interest and Concerns Regarding Growing Bioenergy Crops
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2018	Hurmekoski, E; Pykalainen, J; Hetemaki, L	Long-term targets for green building: Explorative Delphi backcasting study on wood-frame multi-story construction in Finland
2018	Matthies, BD; Vainio, A; D'Amato, D	Not so biocentric - Environmental benefits and harm associated with the acceptance of forest management objectives by future environmental professionals
2018	Merz, S; Williams, R	We All Have a Responsibility to Each Other': Valuing Racialised Bodies in the Neoliberal Bioeconomy
2018	Peltomaa, J	Drumming the Barrels of Hope? Bioeconomy Narratives in the Media
2018	Raimondo, M; Caracciolo, F; Cembalo, L; Chinnici, G; Pecorino, B; D'Amico, M	Making Virtue Out of Necessity: Managing the Citrus Waste Supply Chain for Bioeconomy Applications
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2018	Scordato, L; Klitkou, A; Tartiu, VE; Coenen, L	Policy mixes for the sustainability transition of the pulp and paper industry in Sweden
2018	Stern, T; Ploll, U; Spies, R; Schwarzbauer, P; Hesser, F; Ranacher, L	Understanding Perceptions of the Bioeconomy in Austria-An Explorative Case Study
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Source: Web of Science, compiled by authors

**Table A1 List of all articles covered by the literature review**

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