sustainability

MDPI

Article

One Concept, Many Opinions: How Scientists in Germany Think About the Concept of Bioeconomy

Carmen Priefer [1,2] and Rolf Meyer [1,*]

1 Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT), 76133 Karlsruhe, Germany
2 Department of Nutritional Behaviour, Federal Research Institute of Nutrition and Food (Max Rubner-Institut), 76131 Karlsruhe, Germany
* Correspondence: rolf.meyer@kit.edu

Received: 19 June 2019; Accepted: 1 August 2019; Published: 6 August 2019

Abstract: The official bioeconomy strategies in Europe and Germany pursue a technology-based implementation pathway and stipulate a wide range of objectives to be achieved with a bio-based economy. Reviews of the scientific and societal debate have shown that the technology fix meets criticism and that there is a controversial discussion about possible ways to shape the transition process. Against this background, an online survey was carried out among scientists involved in a regional bioeconomy research program in southern Germany in order to gain insight into their understanding of a bioeconomy. Moreover, the survey provides information about cooperation and major challenges in the future development of three biomass utilization pathways: biogas, lignocellulose, and microalgae. The analysis showed that a resource-oriented understanding of a bioeconomy is favored. The political objectives for a European bioeconomy are widely accepted, and it is expected that ongoing research can significantly contribute to achieving these goals. The two different pathways for shaping the bioeconomy that are discussed in the debate—the technology-based approach and the socio-ecological approach—are considered compatible rather than contrary. Up to now, scientific cooperation has prevailed, while cooperation with societal stakeholders and end-users has played a minor role.

Keywords: bioeconomy; survey; strategies; research program; biogas; lignocellulose; microalgae

1. Introduction

Over the last 10 years, bioeconomy has become an important issue in research and innovation policy, especially in industrialized countries. The core idea of the concept is to replace nonrenewable fossil fuel resources with renewable biogenic feedstock in industrial and energy production. This is meant to pave the way for a more sustainable and eco-efficient economy [1]. Worldwide, a number of countries and international organizations have already developed dedicated bioeconomy strategies, such as the European Union (EU), the Organization for Economic Co-Operation and Development (OECD), the West Nordic countries (Iceland, Greenland, and the Faroe Islands), Australia, Finland, France, Germany, Japan, Malaysia, South Africa, Spain, Sweden, and the United States [2–4]. In other countries, strategies are currently under development. Besides international and national activities, a number of regional bioeconomy initiatives and innovation networks have been established [5]. The Bio-Based Industries Joint Undertaking (BBI JU), a public–private partnership between the European Commission and the Bio-Based Industries Consortium started in 2014 under Horizon 2020, is a key activity at the EU level for implementing the EU bioeconomy strategy [6].

These official strategies use different definitions of bioeconomy, ranging from equalization with biotechnology to a broad societal transition involving a variety of technologies and economic sectors [7,8]. In the literature, it has been pointed out that the terms "bioeconomy" and "bio-based economy" have no clear and binding definition [9]. Definitions strongly depend on the stakeholders involved and their interests, but also show some similarities [10]. Overall, heterogeneous bioeconomy definitions are used for similar contexts.

Various analyses of bioeconomy debates have worked out that different and even contrasting visions and transition pathways are envisioned [7,8,11–14]. Official bioeconomy strategies pursue either a biotechnology vision or a transformation respectively bioresource vision [7,11]. Despite their different foci, all official strategies envision a technology-based transition to a bioeconomy [7]. In the biotechnology vision, economic growth is based on biotechnologies, and the valorization of bioresources is expected to drive economic growth in the bioresource vision [12]. Life sciences and biotechnology and new biomass conversion technologies are seen as enabling technologies in various sectors. A strong partnership between policy, science, and industry; the promotion of international cooperation; the establishment of global value chains; and the granting of patents should improve international competitiveness and contribute to economic growth and employment [8].

In criticism of this understanding, an alternative vision of bioeconomy has been developed in the scientific and societal debate, focusing on socio-ecological aspects and alternatives to the currently dominant model of industrialized agriculture [8]. Rather than concentrating on biotechnology and/or conversion technologies for new value chains, the focus is on agroecological techniques and methods such as increasing plant genetic diversity, improving nutrient recycling, enhancing biodiversity, and improving the health of soil, crops, and livestock. This vision gives high priority to sustainability concerns and calls for a public goods-oriented bioeconomy [14,15]. The contrasting visions have different underlying objectives to be achieved in the context of bioeconomy (See Section 3.4).

The common understanding is that the bioeconomy should contribute to a more sustainable future. However, sustainability is understood differently in the two visions, and the sustainability requirements are often not clearly specified [8]. Common weaknesses and gaps in current bioeconomy strategies are seen in terms of the sound use of land and water resources, waste management along the whole value chain, possible competition between the different biomass end-use sectors, and mechanisms to benefit farmers [1]. Different understandings of the relationship between bioeconomy and sustainability have been identified, ranging from sustainability being an inherent characteristic of the bioeconomy to the bioeconomy having no positive impact and the bioeconomy being disadvantageous for sustainability [16]. This reflects different expectations about the future development of bio-based value chains and especially their environmental impacts.

Regional bioeconomy concepts and activities are expected to play a significant role. Regions are considered to be important in facilitating collaborations between industries and research institutions [17]. In contrast, developing international cooperation is an important objective of national bioeconomy strategies with their technology focus. The desired international cooperation involves different aspects, such as the exchange of information and knowledge transfer, international coordination between research and innovation activities, and the setting up of joint multinational research and technology activities [8]. In addition, a successful transition to bio-based feedstock would require huge volumes of biomass, which could not be mobilized sufficiently in Europe. The consequences could be an expanded international biomass trade and/or the relocation of processing capacities to regions with high biomass potential [18]. Instead, the alternative vision favors home-grown biomass that should be regionally traded and processed [19].

A close interaction between research and industry is a central element in most bioeconomy strategies [7]. The proposed thinking in value chains demands cooperation between different disciplines and actors. However, the establishment of new networks cannot be easily achieved [20] (p. 294).

Against this backdrop of bioeconomy strategies and controversies, the overall aim of our research was to analyze researchers' views on the bioeconomy by conducting an online survey among scientists involved in a regional bioeconomy research program using an explorative approach. The investigation was carried out in the context of the Bioeconomy Research Program Baden-Württemberg, which is funded by the Baden-Württemberg Ministry of Science, Research, and the Arts (MWK). The program aims to improve the strategic position of Baden-Württemberg's research institutions in the field of bioeconomy, provide support in the acquisition of third-party funding, and draw industry's attention to the possibilities of new bio-based products and processes in order to accelerate the transfer of research results into practice [21] (p. 9). The federal state's research landscape is characterized by agricultural and forestry science, biology, biotechnology, chemistry, and process engineering [21] (p. 50).

In the first funding round of the Bioeconomy Research Program Baden-Württemberg, around 50 projects were funded. The research program is thematically divided into the following three fields (hereafter also referred to as clusters or networks):

- Sustainable and flexible value chains for biogas in Baden-Württemberg;
- Lignocellulose as an alternative resource platform for new materials and products; and
- The Integrated use of microalgae for nutrition.

The production of electricity, heat, and methane in biogas plants is a long-established technology in Baden-Württemberg. Biogas is intended to play an important role in Baden-Württemberg's future energy mix, especially for decentralized electricity and a heat supply in rural areas and as control energy to compensate for the fluctuating supply of solar and wind energy. In line with this goal, the projects in this research field explore options for increasing performance and optimizing the process and system integration of existing plants; estimate the potential of alternative substrates such as sewage sludge, residual, and waste materials; and deal with the further technical development of methane production. In contrast to biogas production, the use of lignocellulosic biomass in biorefineries and the industrial use of microalgae are still in the research and development phase. Accordingly, the projects in these two fields are more basic research-oriented. In the lignocellulose cluster, the focus is on improving pulping processes; optimizing synthesis routes; and assessing the availability, combinability, and improvement of feedstocks and the ecological and economic effects of the cultivation and use of lignocellulose. The microalgae research field is mainly concerned with improving extraction methods, optimizing cultivation processes and product quality, and establishing production systems.

The following sections describe the methodology used and present the results of the survey, also addressing similarities and major differences between the clusters. Finally, the main findings are summarized and the results are compared to existing investigations.

2. Materials and Methods

The aim of the survey was to analyze the scientists' understanding of the concept of bioeconomy and their attitudes toward the objectives of selected bioeconomy strategies, to enquire about the current status of the projects (e.g., existing collaborations), to gain insight into certain problem areas (e.g., competing uses and environmental impacts), and to identify similarities and differences between the three investigated biomass value chains. In order to gather this information, an online survey was conducted. All researchers involved in the biogas, lignocellulose, and microalgae networks within the Bioeconomy Research Program Baden-Württemberg (cluster spokespersons, cluster coordinators, project managers, project staff members, doctoral students) were interviewed. Prior to the survey being carried out, the inquiry was announced at the respective cluster meetings in order to attract the interest of the scientists. The survey started in mid-March 2016, and the online questionnaire was open for a period of six weeks. Due to the high number of international scientists in the lignocellulose and microalgae clusters, these groups were also offered an English version of the questionnaire. The survey was developed based on the results of literature reviews on existing strategies [7] and scientific and societal discourse [8]. Before starting the survey, the questionnaire was tested on a group of experts from different scientific disciplines at the Institute for Technology Assessment and Systems Analysis (ITAS) and with spokespersons from the three thematic clusters. The questionnaire (Supplement S1) consisted of five sections:

- Topic 1. Perspectives on bioeconomy;
- Topic 2. Value chains;
- Topic 3. Potentials and competing uses;
- Topic 4. Effects on the environment;
- Topic 5. Collaborations.

Topics 1 and 5 were identical in content for all participants. The questions in Topic 1 addressed the level of agreement with definitions, objectives, and implementation pathways outlined in the bioeconomy strategies and debates. The purpose was to gain insight into the extent to which the bioeconomy strategies serve as a guiding function for researchers in the field. Topic 5 included questions on partners and issues of collaboration in order to identify the prevailing form of cooperation and to assess the extent to which the desired cooperation and networking is realized in the projects of the Bioeconomy Research Program Baden-Württemberg.

The questions in Topics 2 to 4 were adapted to the specific characteristics of the individual clusters. The purpose of the questions was not to obtain exact scientific data, but to elicit the scientists' assessments and personal opinions on the opportunities and limits of the individual biomass value chains based on their experience. The questionnaire included closed and open questions. Depending on the content of the question, multiple answers were possible. This is indicated in the figures, where applicable.

In total, 81 persons participated in the survey, of which only 49 completed the entire questionnaire. In relation to the total number of persons invited to the survey (144), this corresponded to a net response rate of 34%. The response rate was highest in the microalgae research cluster (44%), medium in the lignocellulose cluster (32%), and lowest in the biogas cluster (29%). Nevertheless, the response rates can be considered rather high for a social scientific survey. This success can be explained by the previous promotion of the survey in the cluster meetings. The response rate to questions in Topics 3 and 4 was lower than to those in the first parts of the questionnaire (about 24% on average compared to 34%). A possible reason could be that these questions were primarily related to accompanying research, and not all scientists have expertise in this field. In addition, these sections dealt with future-oriented issues that are still under research. Thus, scientists are not yet in a position to make an assessment. These parts are therefore presented in a qualitative and concise way without the claim of being representative of the opinion of all respondents.

Representativeness for the entire research community cannot be answered conclusively due to a lack of information on personal characteristics (such as age, qualification, position) of the participants in the Bioeconomy Research Program Baden-Württemberg. However, the responses related to scientific background (Section 3.1) indicated that the respondents represented a cross-section of scientific career stages.

The answers were evaluated quantitatively and qualitatively. The open questions were evaluated using the quantitative content analysis according to Mayring [22] in order to build content categories and group the answers into these content categories. The results presented in this paper focus on the scientists' understandings of bioeconomy and on existing collaborations. In addition, the "Results" section sketches challenges for the further development of the three research fields as indicated by the respondents under the topics "competing uses" and "environmental impacts".

3. Results

The following section summarizes the results for all three clusters and identifies the main differences between them. The results are not necessarily presented according to the questionnaire's sequence. Instead, particularly interesting statements, points of clear consensus, or opposing positions are outlined.

3.1. Scientific Background of Respondents

The scientists were asked about which field of activity their project could be assigned to. Multiple answers were possible. According to the responses, the majority (53%) related their projects to biomass production, conversion, and product development. The remaining 47% were assigned to evaluation, systems analysis, and societal framework conditions (Figure 1). Some respondents gave multiple answers, which indicated that their projects deal with different technical or different assessment aspects at the same time or even combine technical and nontechnical research areas such as sustainability assessment. In the biogas cluster, the share of assessment-related research activities was highest, with 58% of the responses. In the microalgae cluster, it was lowest, with 30%. This can be explained by the different development stages of the fields. While the biogas sector is well elaborated from a technical point of view and challenges arise from the lack of competitiveness and acceptance by local residents, microalgae production and conversion is a rather new approach that requires further technical research, with the consequence that an assessment of environmental and societal issues fades into the background.

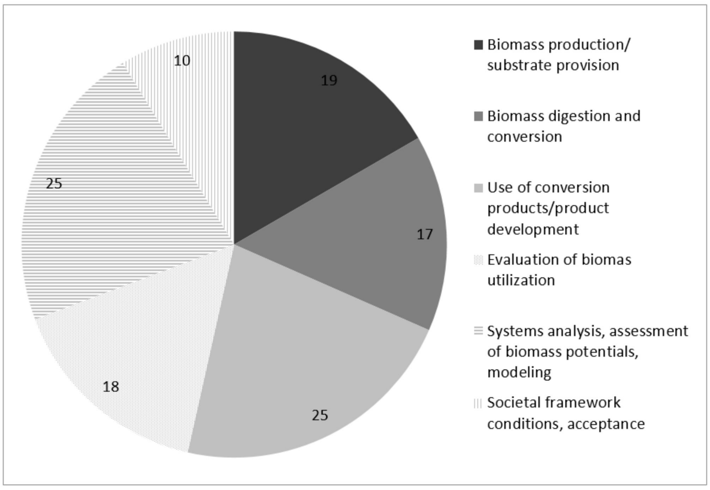

Figure 1. Respondents' assignment of projects to fields of activity ($n = 79$, n = number of answers, multiple answers possible).

Thirty-one percent of the respondents assigned their project to basic research and 69% to applied research (Figure 2). This relation was quite different for each cluster. In biogas research, 96% of the responses referred to applied research, while this share was only 55% in the lignocellulose cluster and 62% in the microalgae cluster. In all three clusters, a limited number of multiple answers were given, i.e., the respective research projects were assigned to both basic and applied research. The number of multiple entries was highest in the lignocellulose cluster, which could indicate that some research projects are in a transition process from basic to applied research or that the nature of the research is both basic and applied due to the interdisciplinary approach of most projects in this cluster. Moreover, the responses indicated that accompanying research projects in the fields of systems analysis, assessment, and societal framework conditions are classified as either basic or applied research.

In answering the question of how long the scientists have been active in the field of bioeconomy, 43% of the respondents stated that they had already done research on bioeconomy before starting the research project with the Bioeconomy Research Program Baden-Württemberg. Fifty-seven percent entered the field at the start of the project (Figure 3). In the biogas network, more than half of the researchers had previous experience in bioeconomy research, and the majority of respondents in the lignocellulose group (59%) first came into contact with the topic through the current project. In the microalgae network, this share was even higher, at 67%. These differences can be explained by the fact that Baden-Württemberg has been seen as a pioneer in biogas research and implementation since the 1980s, while biotechnology-driven microalgae and lignocellulose research are quite new fields. Overall, the answers reflected the mixed composition of the project teams, which consist of professors or project managers with many years of experience in the field of bioeconomy and doctoral candidates who have recently entered the subject.

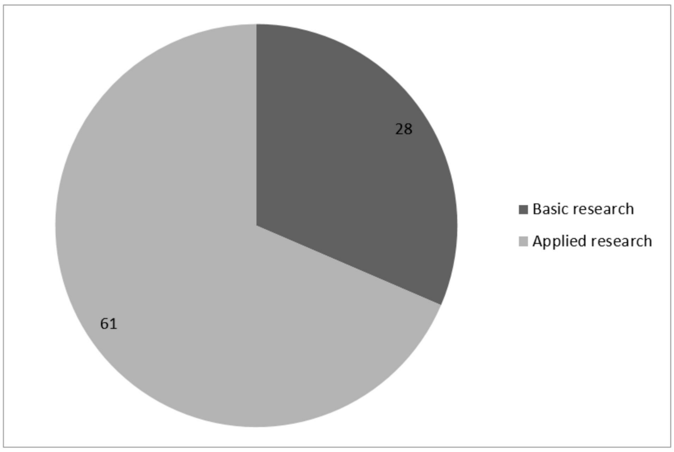

Figure 2. Respondents' assignment of projects to type of research (n = 80, multiple answers possible).

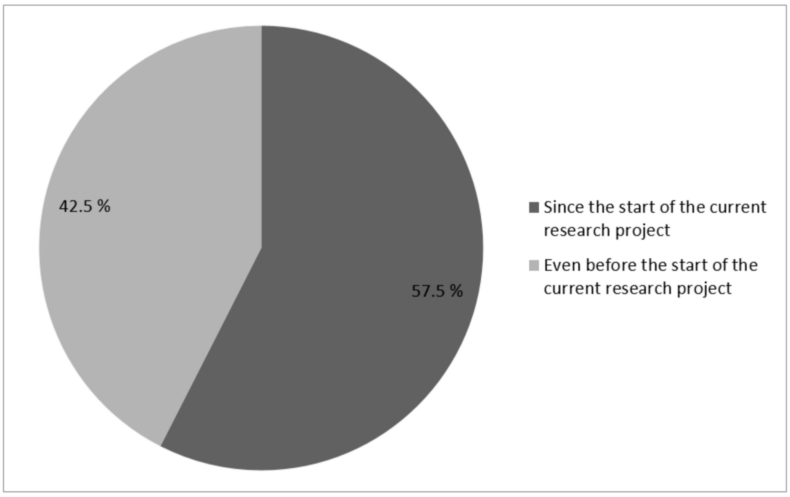

Figure 3. Respondents' familiarity with the bioeconomy topic (n = 80).

3.2. Understanding of Bioeconomy

In a first step, the scientists were asked to define bioeconomy in their own words. The aim of this open question was to get insight into the respondents' understanding of bioeconomy, regardless of already existing definitions.

The 56 definitions given were assigned to the following categories:

- Resource-oriented definition;
- Resource-oriented definition with focus on substitution;
- Resource-oriented definition with focus on sustainability;
- Resource-oriented definition with focus on science and technology;
- Technology-oriented definition.

Almost all of the definitions (89%) saw the production and use of biogenic resources as core elements of the bioeconomy (resource-oriented definition, see Figure 4). Thirty-six percent of the definitions were related to the resource-oriented understanding, and 37% went beyond the pure resource orientation and outlined that biomass use should also meet environmental and social sustainability criteria (sustainability focus). Sixteen percent of the definitions emphasized the substitution of fossil resources with renewable feedstock (substitution focus). Only 7% of the definitions stressed the importance of science and technology in the context of a resource-oriented understanding (science and technology focus). Besides these resource-oriented understandings, 4% of the definitions concentrated on the use of innovative technologies for biomass conversion (technology-oriented definition). While the resource-oriented definition played an important role in all research clusters, the science and technology focus was most supported by respondents from the lignocellulose cluster, and the technology-oriented definition appeared only in the microalgae cluster. Table 1 provides some examples of definitions for the five categories.

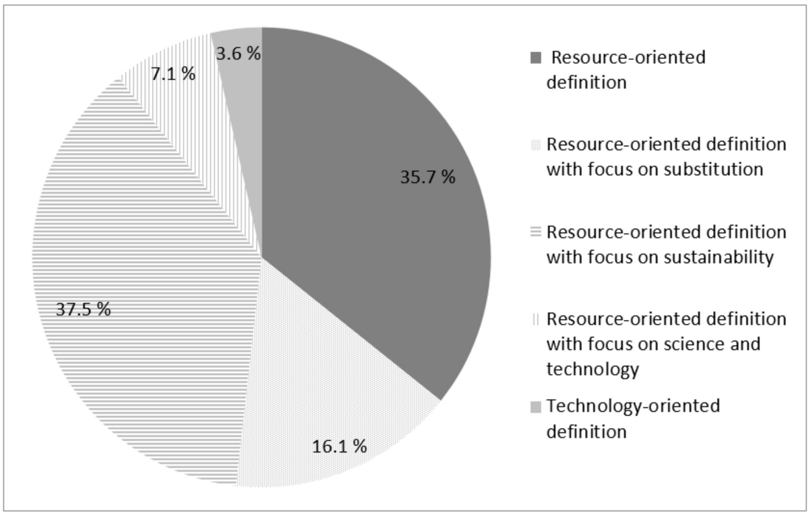

Figure 4. Assignment of the definitions given to categories of bioeconomy understandings (n = 56).

Table 1. Examples of bioeconomy definitions formulated by the interviewed scientists.

Type of Definition	Formulation
Resource-oriented definition	"Any steps involving the production, processing, and use of bio-based raw materials." "Use and efficient transformation of biological raw materials (with complex compositions) into defined products for society/humans."
Resource-oriented definition with focus on substitution	"Bioeconomy is the approach to replace the petrochemical-based industry with a bio-based industry, i.e., through renewable raw materials and residues." "Using biomass, instead of fossil fuel, to provide renewable and green energy and food, and establishing a whole industrial and social circulation."
Resource-oriented definition with focus on sustainability	"Bioeconomy describes an economy based on renewable raw materials instead of fossil raw materials. Furthermore, the economy should be as environmentally friendly and sustainable as possible." "Transformation process of an economy that is characterized by fossil fuels, profit, and exploitation (nature and humankind) toward an economy that is based on the careful use of renewable resources, with particular attention to social and ecological effects."
Resource-oriented definition with focus on science and technology	"Bioeconomy means using biological resources. Bioeconomy is based on the latest scientific findings and builds a bridge between technology, ecology, and an efficient economy." "Bioeconomy encompasses the sustainable production of biological resources and their conversion into food, feed, and high-value products/energy via innovative technologies from academic and industrial origins."
Technology-oriented definition	"Bioeconomy is a novel economic pattern that would generate economic effectiveness based on the research and application of biotechnology." "Bioeconomy is the combination of biotechnology and economy. That means it is based on the technology of biology to produce biomass, explore and apply production in order to gain economic benefit."

In a second step, the respondents were asked to indicate to what extent they agree with the definitions formulated in official bioeconomy strategies. This question aimed to find out about support or skepticism toward official bioeconomy definitions by scientists working in the field of bioeconomy.

The OECD definition was selected as an example of a technology-oriented understanding. The European Commission's definition focuses on the sectors involved in the bioeconomy (sector-oriented definition). The German Federal Ministry of Education and Research based its definition on the resources used (resource-oriented definition), and the definition by the German Federal Ministry of Food and Agriculture can be seen as an example of a target-oriented definition. The wording in the questionnaire was as follows:

- **Technology-oriented definition.** Bioeconomy is the development and application of modern biotechnology and life sciences (OECD [23]);
- **Resource-oriented definition.** Bioeconomy covers agriculture and forestry as well as all producing sectors with their respective service sectors that develop, produce, process, and work on biological resources (plants, animals, microorganisms) or use them in any form (Federal Ministry of Education and Research [24]);
- **Sector-oriented definition**. Bioeconomy covers the production of renewable biological resources and their conversion into products that generate additional value, such as food and animal feed, bio-based products, and bioenergy (European Commission [25]);
- **Target-oriented definition**. Bioeconomy combines economy and ecology in an intelligent way and thus enables bio-based and sustainable economic growth (Federal Ministry of Food and Agriculture [26]).

Overall, all types of definitions originating from official bioeconomy strategies were supported by the majority of respondents (Figure 5). However, the highest level of full agreement (over 60%) was recorded for the resource-oriented definition, followed by the target-oriented definition. This was in line with the results of the respondents' own definitions, where the majority of definitions were solely resource-oriented or had an additional focus on sustainability. The sector-oriented definition showed a lower level of full agreement. Nevertheless, summing up the answers "fully agree" and "rather agree", the sector-oriented definition received the highest agreement, together with the resource-oriented definition. The lowest level of full agreement was achieved for the technology-oriented definition. The proportion of people slightly disagreeing with this definition was highest, about 30%. The comparison to the researchers' own definitions showed that the given technology-oriented definition received more support than a similar understanding formulated by the respondents themselves.

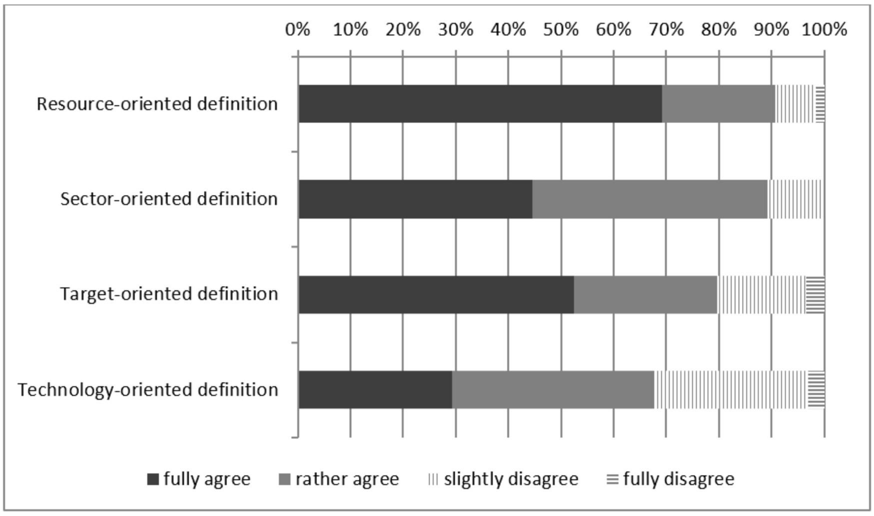

Figure 5. Respondents' agreement with official bioeconomy definitions differing in their thematic focus (n = 66).

When looking at the different research clusters, it became obvious that researchers from all clusters strongly agreed with the resource-oriented definition, which was in accordance with the researchers' own understanding. While the majority of the biogas cluster respondents rejected the technology-oriented definition, agreement was rather high among the respondents from the microalgae cluster, where biotechnology plays an important role.

3.3. Visions and Objectives

The bioeconomy strategies of different countries and institutions include visions and far-reaching societal goals that should be achieved through the realization of a bio-based economy. The researchers were asked to rate the goals of the German Policy Strategy Bioeconomy according to their importance. The goals relate to sustainability issues, international competitiveness, specific fields of technology and research, as well as cooperation between science, business, and society [26] (pp. 20 ff.). The results showed that all objectives were predominantly considered essential or important (Figure 6). The majority of the respondents viewed the following two targets as essential: "production of raw materials in line with environmental and climate protection" and "conversion of the economic production base from fossil to biogenic sources in the long run". This result matched well with the respondents' predominant agreement with the resource-oriented definition of the bioeconomy (see Section 3.2). Furthermore, the goals "implementation of cascade use", "sustainable consumption", "networking between science and business", as well as "inter- and transdisciplinary research" were regarded as relevant. The leading role of Germany in solving global challenges was rated as the least important goal. Between 20% and 30% of respondents considered "economic growth", "job creation", "strengthening of industrial biotechnology as an economic field", and "international competitiveness" as less important.

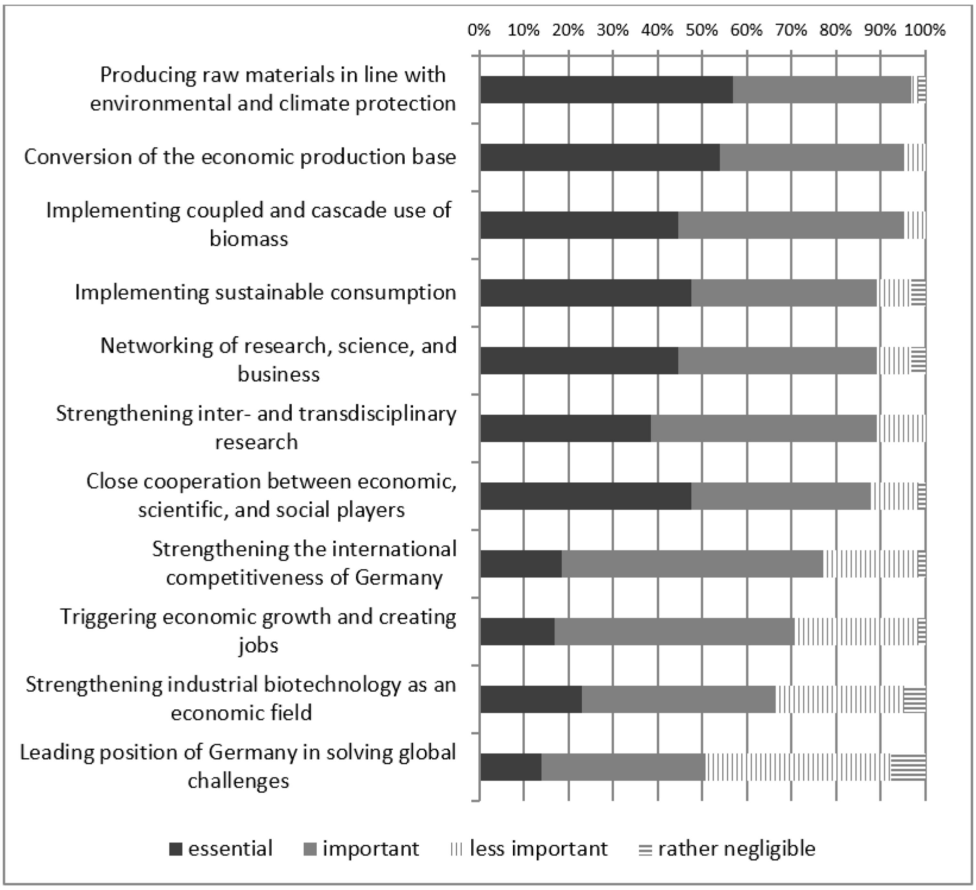

Figure 6. Respondents' evaluations of the objectives of the German Policy Strategy Bioeconomy according to importance (n = 65).

The comparison between the clusters showed that the aim of Germany taking a leading role in solving global challenges was considered to be of little importance in the biogas and microalgae clusters, while the lignocellulose network considered this goal essential or important. The production of raw materials in line with the objectives of environmental and climate protection was regarded as less important in the microalgae group than it was in the biogas and lignocellulose consortium, for which the proportion of "essential" mentions was significantly higher. This may have been due to the fact that microalgae production is a technical process that is independent from agricultural production and does not compete for land resources with other biomass utilization pathways such as food production. Furthermore, it is striking that half of the respondents from the microalgae cluster considered a strengthening of industrial biotechnology essential or important, while the other half considered this less or not important. Thus, there were different views on the economic importance of the broad industrial application of biotechnology in the algae network, which could be explained by the early development stage of algae technologies and the resulting uncertain applications. The majority of respondents from the biogas cluster attached importance to strengthening industrial biotechnology as an economic sector with great market and value-added potential, while the majority of this group refused to equate bioeconomy with modern biotechnology (see Section 3.2). This was in line with the prevailing understanding in Germany (and the EU) that biotechnology is a key technology, but also that relevant technology and innovation approaches to bioeconomy comprise more than biotechnology.

In addition, participants were asked to assess the expected contribution of their research to the objectives of the Baden-Württemberg Research Strategy Bioeconomy. The objectives were related to, e.g., the country's resource independence; competitiveness and innovation capacity; new conversion technologies and bio-based products; local value and job creation; and the information flow between business, research, and society [21] (p. 8 f.). Nearly 70% of respondents answered that their project results could contribute significantly or moderately to "using the country's diversity of plant biomass", followed by "developing new technologies for the conversion of biomass", "increasing international visibility and competitiveness of the country", and "networking between the country's research institutes" (Figure 7). The fact that the most significant contributions were expected for "developing new technologies for the conversion of biomass" and "developing new bio-based substances and materials" could be explained by the technical focus of many projects. The proportion of respondents saying that their research could only make a small or even no contribution was over 50% and 60%, respectively, for the objectives "developing cascade systems" and "safeguarding a high standard of nutrition".

The comparison between the clusters showed that the differences were quite small. One major difference was that the respondents from the microalgae cluster indicated that their projects could contribute to ensuring a high standard of nutrition, while this was, of course, not the case in the biogas and lignocellulose teams. It should be noted that, logically, the specific projects cannot contribute to all objectives of the research strategy, but only a few. In particular, answers from the accompanying assessment projects showed that some of them can only make limited contributions to achieving the strategy's objectives, since critical reflection rather than fulfillment of objectives is in the foreground of this type of research.

3.4. Alternative Implementation Pathways

Both in scientific and societal debate on the concept of bioeconomy, different implementation paths are discussed. An analysis of the European discourse, carried out by the authors of this article, revealed that the understandings can be assigned to two main strands of discussion: the technology-based and socio-ecological approaches [8]. Based on a selection of contrasting positions (Table 2), respondents were asked to indicate to what extent they agreed with individual elements of possible implementation pathways. The selected positions covered a wide spectrum of topics relevant to the bioeconomy, from resource use and consumer behavior to innovation focus and production approach to perspectives on nature and participation.

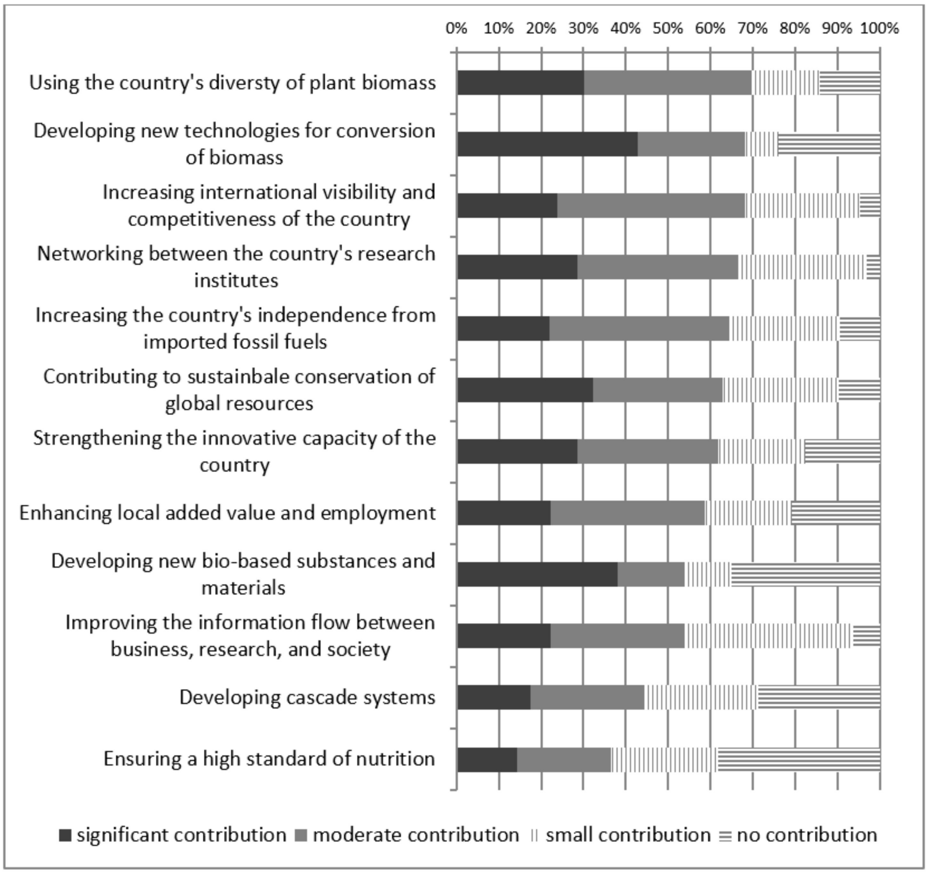

Figure 7. Contribution of the projects to realizing the objectives of the Baden-Württemberg Research Strategy Bioeconomy (n = 63).

Table 2. Compilation of contrasting positions on shaping the future bioeconomy.

Elements	Technology-Based Approach	Socio-Ecological Approach
Resource use and consumer behavior	Improving resource efficiency along bio-based value-added chains (less raw material input per product unit, closed cycles, coupled and cascade use)	Promoting sustainable consumption patterns (e.g., reducing meat consumption, consuming regionally produced food, avoiding food waste, reducing fossil energy use)
Innovation focus	Extending technological leadership, intellectual property (e.g., patents), and economic influence of multinational organizations	Promoting social innovations and the use of local knowledge and experience of various stakeholders (farmers, small and medium-sized enterprises, non-governmental organisations)
Production approach	Promoting research and innovation in the field of life sciences as key technologies (genetic engineering, synthetic biology, DNA sequencing, bioinformatics, etc.)	Strengthening multifunctional, agroeconomic land cultivation oriented toward criteria such as diversity, resilience, and self-regulation
Perspectives on nature	Adjusting nature to industrial processes and cycles	Adjusting industrial metabolisms to natural cycles
Participation	Establishing close partnerships between companies, research, and politics to promote investments, skills, and experiences in the fields of key technologies	Involving civil society in shaping and advancing the bioeconomy

Source: Excerpt from Reference [8] (p. 15).

The majority of participants agreed with all statements, except for two (Figure 8). The highest level of full agreement (more than 50% and 60% of the respondents, respectively) was with "improving resource efficiency" and "promoting sustainable consumption". Total agreement was very high (nearly 90% up to 100%) for the elements "improving resource efficiency", "adjusting industrial metabolisms to natural cycles”, “establishing close partnerships between companies, research, and politics in the fields of key technologies”, “strengthening multifunctional, agroecological land cultivation”, and “involving civil society in shaping and advancing the bioeconomy”. Agreement with statements on shaping the future bioeconomy was in line with the respondents’ evaluations of the objectives of the German National Policy Strategy Bioeconomy (see Figure 6). This was especially the case for improved resource efficiency for environmental and climate protection, sustainable consumption, and close cooperation between companies, research, politics, and social players.

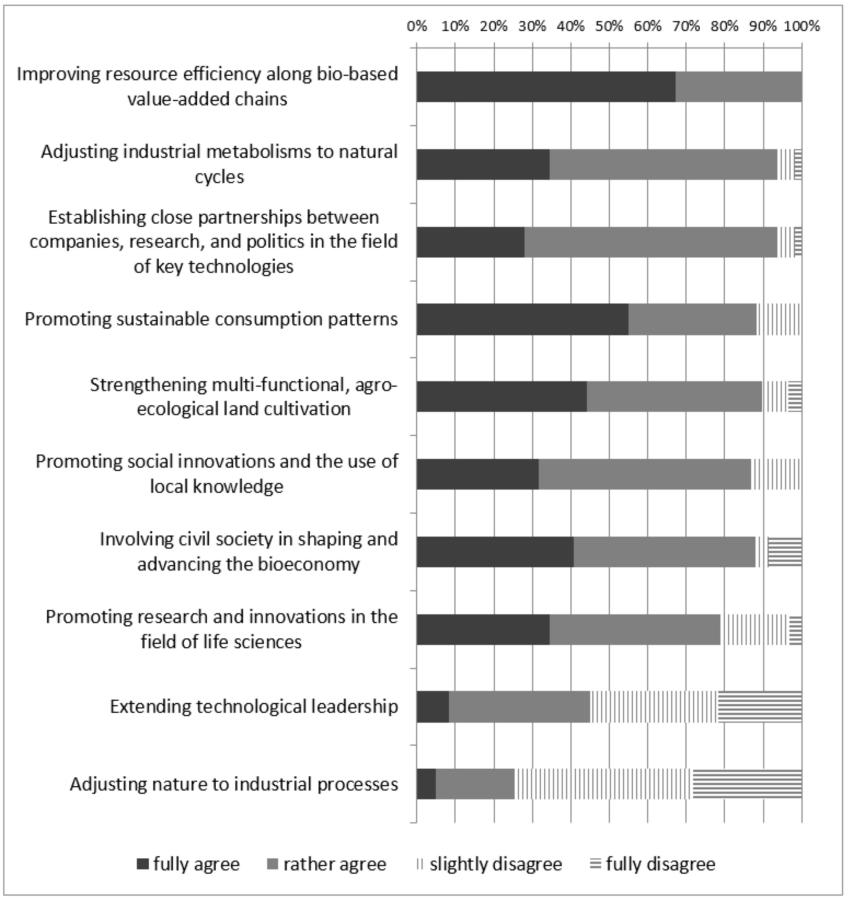

Figure 8. Respondents’ agreement with selected positions on shaping the future bioeconomy (n = 61).

All in all, the agreement levels were rather similar for all points, which means that the participants considered the positions complementary and not mutually exclusive. Disagreement was expressed by more than 50% and 70% of the respondents, respectively, for the elements “extending technological leadership” and “adjusting nature to industrial processes”. The relatively low importance attached to the objective “strengthening the international competitiveness of Germany” corresponded with the limited support for the statement “extending technological leadership”.

The research clusters showed some differences. While the biogas and microalgae networks strongly disagreed with “extending technological leadership, intellectual property (e.g., patents), and economic influence of multinational companies”, the majority of respondents from the lignocellulose cluster agreed with this approach. One reason for this could be that there is considerable innovation potential in the field of lignocellulose utilization and biorefinery concepts, combined with the ambition to take a pioneering role. Another difference intrinsic to the topics of the three clusters was that full agreement with “promoting research and innovation in the field of life sciences” was highest in the microalgae and lignocellulose networks, while this played a less important role in the biogas network.

3.5. Existing Collaborations

Another part of the questionnaire was about ongoing collaborations the scientists from the research program are involved in (Figure 9). The majority of respondents answered that they were engaged with scientific partners within the cluster and the overall research program. Moreover, collaborations with scientific partners all over Germany and Europe were quite common. A smaller proportion of respondents was involved in collaborations with industry, in particular with companies in the fields of renewable energies, biotechnology, chemistry, and the food industry. Only a small number of respondents cooperate with societal stakeholders and users, with cooperation with users and farmers or agricultural organizations being more common than with nongovernmental groups.

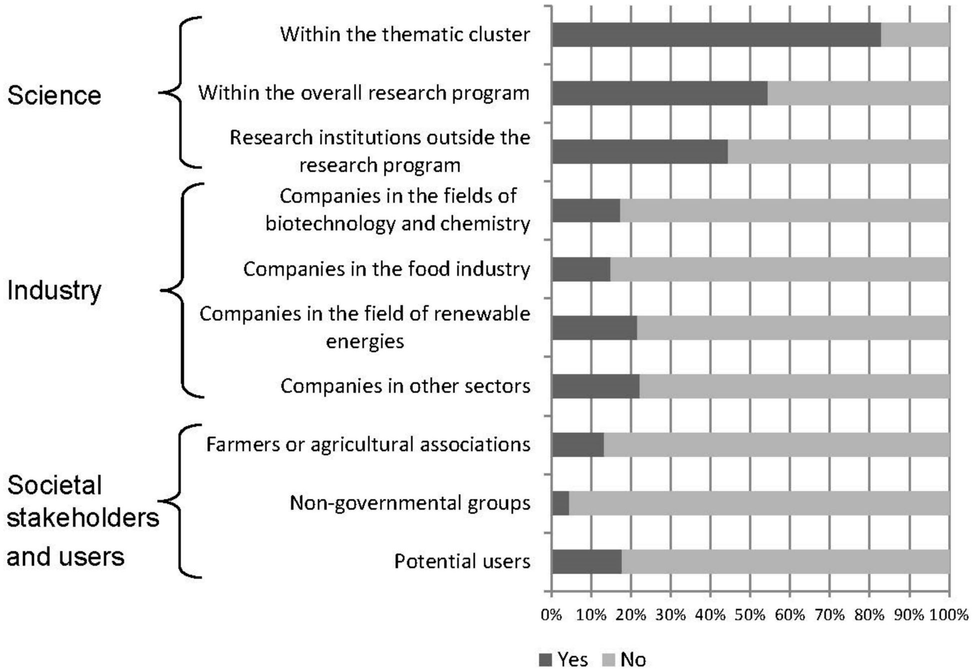

Figure 9. Respondents' collaborations with different types of partners ($n = 48$).

The comparison between the clusters showed a quite similar picture. One difference was that the biogas cluster had more collaboration with farmers and users compared to the other networks. This was due to the fact that manifold contacts have been established during the long history of biogas research in Baden-Württemberg, while the other two topics are quite new and cooperation still needs to be further developed.

Moreover, the scientists were asked to classify their networking activities according to forms of cooperation (Figure 10). The responses showed that traditional forms of scientific cooperation prevail, such as the exchange of information and results, joint definitions of research questions, agreement on methods, joint use of equipment, and agreement on raw materials. The majority of respondents indicated that their collaborations aim to sound out common interests, and only a marginal proportion is involved in collaborations aimed at discussing marketing strategies and developing new business models.

The clusters differed with regard to the discussion and exchange of results. This point was mentioned most frequently in the biogas group. This may have been due to the fact that, in the biogas network, there is a focus on applied research, which takes place in cooperation with partners from practice and involves more exchange, while the lignocellulose and microalgae networks conduct more basic research, which implies increased joint use of equipment and infrastructure and increased coordination of the raw materials to be used. In the microalgae cluster, the different forms of scientific communication play an even more important role than in the other clusters. A possible reason for this could be the specific structure of the research network, where the projects are arranged along the value-added chain from algae cultivation, extraction of ingredients, and conversion up to product design. The project members are therefore dependent on the results of the previous stages, which leads to closer coordination.

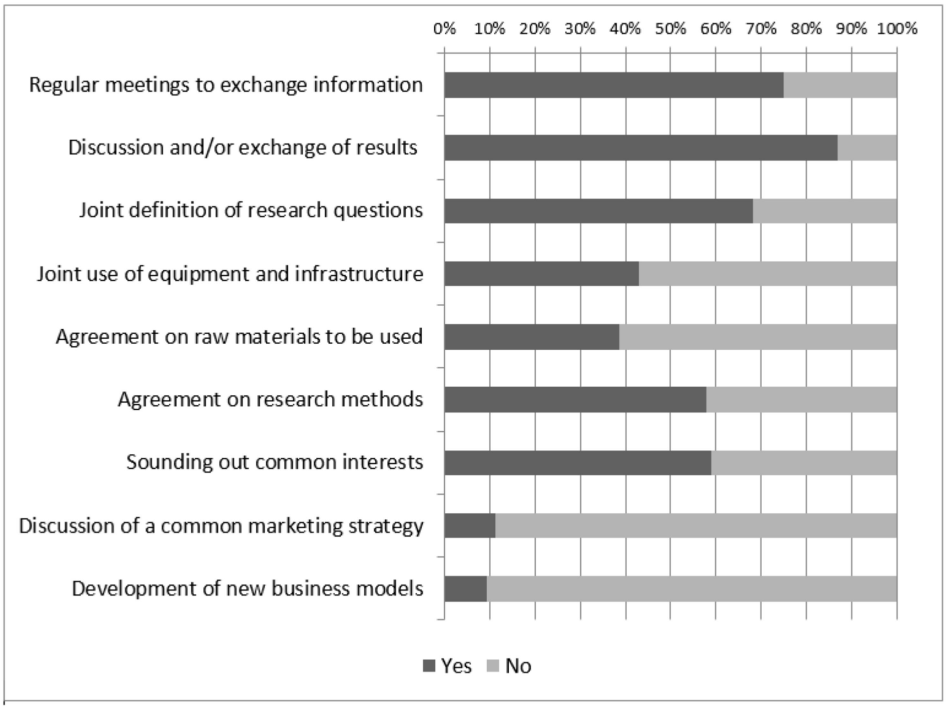

Figure 10. Respondents' forms of cooperation (n = 48).

3.6. Obstacles to the Further Development of the Thematic Fields

The participants were asked about possible obstacles to the realization of the biomass value chains they are working on. This included a discussion of competing uses, environmental impacts, and acceptance of the production process or end products by local residents and end users.

3.6.1. Biogas Value Chain

Due to the limited potential of primary biomass and the discourse about adverse effects of energy crop cultivation, there have been attempts to put a stronger focus on the use of residual and waste materials for biogas production in Germany. In our survey, the researchers outlined some challenges for switching to these sources. First, they emphasized that, even with increased mobilization of residues, the demand for energy crops would probably remain the same. Arguments for this assessment were that, on the one hand, the available residual and waste materials would not be sufficient to cover the raw material requirements of the existing biogas plants. On the other hand, it was argued that such feedstocks were technically unsuitable for use in agricultural biogas plants previously operated with energy crops. Second, it was assumed that the expansion of waste fermentation plants would continue to increase. In addition, economic reasons (high transport costs) and legal obstacles (the need to reauthorize agricultural biogas plants) would militate against the widespread use of residual and waste materials. Moreover, it was expected that this could lead to competition between the biogas and lignocellulose paths with regard to certain feedstocks such as landscape conservation material. Third, for this kind of biogas production, the majority of respondents considered sites close to settlements to be useful or necessary, with increased use of alternative substrates such as food waste. This would be useful particularly from an ecological point of view and would also offer possibilities for heat utilization. The respondents mentioned positive examples of near-settlement facilities planned with the involvement of local residents, but also mentioned counterexamples. The main obstacles were seen in the legal requirements for waste fermentation plants and in acceptance by local residents. In addition, respondents expressed doubts about the expected positive environmental impacts related to the use of perennial energy crops, waste, and residual materials.

3.6.2. Lignocellulose Value Chain

The availability of woody biomass was mentioned as a central challenge to the implementation of novel lignocellulose-based value chains. Some respondents assumed that unused wood potential exists, in particular in private forests and in the form of alternative feedstocks such as landscape conservation material, agricultural residues (e.g., straw), and wood waste from the private and commercial sectors. In contrast, the majority of respondents argued that alternative feedstocks are limited and not sufficiently available. Some of the reasons mentioned were competing uses (e.g., the use of agricultural residues in biogas production), conflicts in objectives (e.g., nature conservation opposes the removal of dead wood and cortices from forests), and technical obstacles (e.g., the need for a uniform lignin quality in certain conversion processes, which cannot be ensured when using residues). The majority of respondents expected increasing competition for raw materials, especially in the energy wood market. It was assumed that the innovative value-added chains aspired to by the research cluster would rarely compete with the wood, paper, construction, and furniture industries, but that there might be synergies with these industries in using their residual materials or byproducts.

3.6.3. Microalgae Value Chain

Numerous inhibiting factors were identified for the production and use of microalgae, in particular related to the consumption of resources, acceptance, and competitiveness of algae production. In algae production, there is a considerable need for nutrients, energy, and other inputs. Nitrogen, phosphate, and iron are the main nutrients. If large algae yields are to be achieved, the estimated nutrient requirements are high, but this depends on the type of algae and the cultivation method used. Theoretically, wastewater streams as well as sea and brackish water could be used as nutrient sources. In practice, there are legal barriers because the specifications for nutrient sources used in food production are very high. The use of synthetic fertilizers therefore seems likely. Moreover, further adjuvants and process substances are needed: CO_2, ethanol as an extraction agent, flocculants, disinfectants for the sterilization of reactors, and herbicides. In particular, CO_2 demand is a limiting factor for the cultivation of algae. To ensure the safe use of algae as food, exhaust gases can only be used if no contamination with pollutants can be guaranteed. Therefore, combustion gases cannot be used.

The energy balance of algae production was predominantly classified as negative, though optimization potential was expected from autotrophic cultivation, cultivation in the field, and process improvements. Moreover, industrial algae production has high space requirements. Integration into the city landscape is considered possible. Few respondents expected major impacts on the landscape. However, it was emphasized that there has been no experience with visual impacts and acceptance of larger systems until now. Consumer acceptance is a key factor for realizing the potential of microalgae in nutrition. A clear majority of respondents considered consumer acceptance to be high, especially with regard to use as food ingredients, e.g., in functional foods. Acceptance was expected to be particularly high among younger, health-conscious and environmentally conscious consumers. Acceptance of algae as a substitute for animal-derived food was assumed to be rather low. The following inhibiting factors were mentioned: highly technically processed products do not meet the demand for naturalness; quality losses due to bacterial contamination; difficult imitation of the taste of meat in connection with cultural reservations about the color, taste, and smell of algae; and low popularity in general. Almost all respondents assessed the food industry's interest in algae-based products to be very high, especially with regard to algae-based ingredients and niche products (e.g., in the vegan food sector or fitness industry). However, there was consensus that the demand will hardly shift from animal-based food products to algae-based products. Besides the lack of consumer acceptance, the main reason is the lack of competitiveness of algae products.

4. Discussion

4.1. Predominance of Resource-Oriented Understanding of Bioeconomy

The definitions of bioeconomy, expressed in the responding scientists' own words, with or without specifications, were predominantly resource-oriented. In line with this, the resource-oriented definition presented in the questionnaire achieved the highest agreement of all official definitions. According to this definition, bioeconomy is related to the production, conversion, and use of biological resources. Thus, the scientists' understanding of bioeconomy was strongly in line with the political understanding in Germany and Europe. This was confirmed by recent findings from Austria [12] and Norway [27], which also indicated the dominance of a bioresource-based understanding of bioeconomy among stakeholders. In the same way, the resource-oriented definition by the European Commission was generally supported by respondents (mainly from science and industry) in a public consultation in preparation for the EU Bioeconomy Strategy [28].

The great consistency in the bioeconomy understanding can be explained by the high engagement of scientific communities in the development of official bioeconomy strategies, both at the European and national level [7]. In Baden-Württemberg, for example, scientists were asked to participate in a steering committee and to develop proposals for strategic orientation [21].

Scientific analyses of bioeconomy strategies interpret different definitions as an indication of divergent understandings of bioeconomy (e.g., Reference [10]). In our survey, the technology-oriented definition was less supported than others, but all proposed definitions were agreed upon by the majority of respondents. Agreement with the technology-oriented definition was higher in the lignocellulose and microalgae networks. This preference can be explained by the stronger role of biotechnology in their research agenda. Despite the resource-oriented definition in official bioeconomy strategies, modern biotechnology is also regarded as a key technology in these strategies (e.g., Reference [24]). Overall, the high level of agreement with various definitions indicates that they are not perceived as contrary, but as complementary.

4.2. High Expectance of Contribution of Research Activities to Objectives of the Regional Bioeconomy Strategy

The goals of the German Policy Strategy Bioeconomy were widely supported by the respondents. Only the goal of taking on a leading role in solving global challenges such as climate protection and food security was seen rather critically. Key objectives in all clusters were "the production of raw materials in line with the objectives of environmental and climate protection and nature conservation" and "the long-term conversion of the economic production base from fossil to biogenic sources". Technology visions and objectives of official strategies can fulfill a guiding function for researchers and actors in the respective research area [29]. Our survey results indicated that the official objectives are well integrated into the thinking of the researchers. It can therefore be assumed that the official bioeconomy strategies achieve the objective of providing guidance.

In a similar way, an evaluation of the German Research Strategy Bioeconomy has shown that there is strong support for the overall approach oriented toward societal goals, though there is a lack of agreement on specific objectives among the heterogeneous research communities involved in bioeconomy research [20].

The majority of respondents expected their research results to make a high or medium contribution to achieving the objectives of the Baden-Württemberg Research Strategy Bioeconomy. There were differences between the research clusters regarding the extent of their contributions to the different objectives. This resulted from different research agendas. Of course, an individual research project can only contribute to a few objectives of the research strategy.

An evaluation of the German Research Strategy Bioeconomy [20] and the European Bioeconomy Strategy [30] showed that funded research has significantly contributed to achieving overall goals and that the majority of funded projects have aligned their objectives to the strategies. The EU review outlined that "there is early indication that the projects funded are generating relevant excellent multidisciplinary research (i.e., the quality of publications in terms of citations)" [30] (p. 12).

4.3. Simultaneous Support for the Elements of Different Pathways in the Implementation of the Bioeconomy

Different implementation pathways are discussed for the development of the bioeconomy (e.g., References [11,14]. They are usually presented as alternative trajectories. In our survey, not all elements of the official technology-based approach were supported by the majority of respondents. For example, "adapting nature to industrial processes" and "extending technological leadership" as key elements of the technology-based approach were approved only by a minority. At the same time, some key elements of the socio-ecological implementation pathway met with much approval: for example, "promoting sustainable consumption patterns" and "strengthening multifunctional, agroecological agriculture" were supported by nearly 90% of the respondents. Similarly, stakeholder surveys in Denmark and the United Kingdom, based on interviews, pointed to a potential overlap of the two approaches, which could give rise to a new concept of quality industrial biomass production, understood as using superior biomass quality attributes in place-specific biorefineries to produce different products depending on the region [19].

Obviously, the survey participants considered the discussed implementation pathways of the bioeconomy as compatible or, more precisely, as combinable. This perception might have been due to the fact that projects on agroecology, local food chains, citizens' initiatives, and so on are incorporated in EU and national research programs, even if only marginally in comparison to the dominating technology-centered funding. However, in the background of this allegedly equal coexistence, rival stakeholder networks compete for influence on research priorities, policy changes, and the preferable bioeconomy trajectory [31].

With regard to sustainable development, the current EU bioeconomy policy is seen to lean strongly toward weak sustainability and to favor economic dimensions and concerns over environmental and social dimensions [32]. In addition, current developments in bioeconomy sectors adhere largely to the principles of weak sustainability [33]. The respondents' strong support for some elements of the socio-ecological approach in the survey can be interpreted as the scientists' recognition of the need for strong sustainability in the bioeconomy.

The assumed combinability of elements from different implementation pathways contrasts with the irreconcilability of pathways formulated in scientific and societal discourses on bioeconomy. While the technology-based approach is understood as an enhancement of current practices in the production, processing, and consumption of biomass with new products and more environmentally friendly technologies, the socio-ecological pathway is conceptualized as a structural remodeling of today's production and consumption practices and as fundamental changes in the ways of thinking and living [8]. The divergence between survey statements and discourse viewpoints can be interpreted in two ways: the compatibility between the two perspectives has not been considered sufficiently in the discourse, or the interviewed scientists underestimate the tensions or potential conflicts between the two approaches. This question cannot be answered within the present study, but some indications can be given:

- Since the bioeconomy has not yet been widely implemented, potential conflicts have not yet fully materialized. Therefore, they are probably underestimated. At the moment, different ideas continue to coexist, and the pressure to decide between the given alternatives is not yet high enough;
- Systemic studies on the connection between the bioeconomy and its wider societal and economic implications are still in their infancy. It remains to be seen whether and how the transition to a bioeconomy will contribute to solving key challenges [11]. Addressing environmental and social concerns and limits has been repeatedly demanded, but is not easy. It is, therefore, difficult to appraise the best implementation pathway for the bioeconomy;

- Competing interests, power relations, and politics are inherent in bioeconomy development and make it difficult for stakeholders to negotiate compromises and reach consensus on the most sustainable pathways for the future [34]. Biomass produced from agriculture is subject to ongoing debates about the future of agriculture. Agricultural paradigms carry their own set of ideological and value assumptions and are fiercely contested by critics [19]. Scientists engaged in bioeconomy research are probably not familiar with these debates.

The evaluation of the German Research Strategy Bioeconomy has also shown that the heterogeneous scientific communities interviewed do not share a common understanding of implementation pathways for the bioeconomy up to now [20] (p. 296). Some of them call for more technical and laboratory research in the field of biotechnology; others want to foster more non-technical research in the fields of sustainability and social innovation.

4.4. Prevailing of Scientific Collaborations

The research clusters had in common that most of their collaborations take place within the scientific system, and only a few collaborations exist with societal stakeholders and users. There are certain peculiarities in the biogas network, where cooperation with the latter group of players and industrial companies is more frequent than in the lignocellulose and microalgae networks. With its long-established biogas technologies, this cluster has been able to build extensive networks with industry and other stakeholders, whereas in the fields of lignocellulose and microalgae, partnerships and cooperation are still evolving due to the early stage of development of the technologies. Overall, the forms of cooperation are dominated by conventional scientific formats, such as meetings for exchanges of information, discussions of results, and the development of research questions, while there are only a few cooperation formats for discussing joint marketing strategies and developing new business models. One reason could be that, in the lignocellulose and algae networks, basic research is in the foreground, and therefore the marketing of products lies in the future.

Similarly, the involvement of societal stakeholders has been lagging behind the European level. As highlighted in a review of the European Bioeconomy Strategy from 2012, the Bioeconomy Panel is the central body for implementing "Area of Action 2: Reinforced Policy Interaction and Stakeholder Engagement" [30] (p. 13). The panel was created in 2013 to support interactions between different policy areas, sectors, and stakeholders in the bioeconomy. So far, the main outputs of the panel have been four bioeconomy stakeholder conferences, held between 2012 and 2016, and the 2017 "Stakeholders Manifesto" [35]. The latter represents a marked shift to the European Commission's own strategy paper from 2012 [12]. It should be taken into account that the panel was established on political initiative. The review provided no information on the level of involvement of societal stakeholders in European research projects. A group of experts evaluating the European strategy concluded that initiatives such as the Stakeholder Panel have increased awareness of the bioeconomy concept among a broad range of stakeholders, but that the involvement of public and private stakeholders and civil society organizations should be reinforced with an updated "Bioeconomy Strategy and Action Plan" [36].

The evaluation of the German Research Strategy Bioeconomy showed that the experts surveyed considered it necessary to incorporate a wide range of stakeholders in research, from business and industry to NGOs in the fields of environment and consumption to citizens and the broader public [20] (p. 285). However, until now, funding aimed at fostering dialogue with civil society and the public has been rather rare, and these groups have been only marginally addressed in the existing funding scheme [20] (p. 293, 296). An evaluation of the individual projects revealed that the goal of intensifying networking with partners and establishing new networks was reached less frequently than that of scientific knowledge exchange and interdisciplinary learning [20] (p. 294).

5. Conclusions

The survey results showed that the scientists involved in the Bioeconomy Research Program Baden-Württemberg agreed with and orient themselves toward the official bioeconomy strategies.

The strategies have thus met the objective of becoming an important guiding tool for research activities. The guidance provided by the strategies could lead to a narrowing of technology options and implementation pathways. Then again, the official bioeconomy strategies could be seen as important catalysts for the development of alternatives, which has been part of a critical discussion in the last years. This interplay between closing and opening pathways for implementation of the bioeconomy demands further investigation. On the one hand, the emergence of alternative bioeconomy approaches, the establishment of actor networks supporting these alternatives, and their influence on policy-making require further scientific investigation. On the other hand, official bioeconomy strategies should include reflexive elements, opportunities for new technical ideas, and space for nontechnical ideas and social innovations. In this way, bioeconomy policies could contribute to the development of enhancements and alternatives to existing approaches rather than deal with critical appraisals from the outside.

Our results showed that the surveyed scientists tend to consider the different implementation pathways for the bioeconomy to be combinable, while in the scientific and societal debates, these are seen as contradictory. In conclusion, it can be stated that the majority of respondents support combining alternative and well-established practices and ideas. More research is needed to better understand how realistic such combinations are in practice. The next step after analyzing competing narratives would be to translate them into scenarios and to examine their preconditions and impacts.

Anyway, a critical reflection of goals and implementation pathways, taking into account societal expectations, is of crucial importance in any update process of bioeconomy strategies. Aspects that are not considered at this stage will most probably not be included in the following research funding. The involvement of civil society is still in its infancy and needs to be further developed. The drafting of new or the revision of existing bioeconomy strategies should be set up as a participatory process that includes a broad spectrum of stakeholders and viewpoints.

The development of the bioeconomy as a comprehensive sociotechnical transformation requires interdisciplinary but also transdisciplinary research approaches. The Baden-Württemberg Bioeconomy Research Program, with its interdisciplinary orientation, largely meets this requirement. Consequently, the results of the survey partly reflected these specific research conditions. For instance, the respondents' understanding of the bioeconomy was closely linked to sustainability issues. In addition, they described several challenges for the future development of the three biomass value chains, emphasizing that sustainability is not easy to achieve and that research needs to be intensified in this field. The analysis of collaborations revealed that exchange within scientific communities prevails. Cooperation with industry, other business actors, and end-users is relatively weak, but is commonly called upon as needing to be intensified. However, it remains open how well stronger cooperation with potential users of new bioeconomy technologies for accelerated adoption goes together with intensified examination of sustainability issues. This tension, e.g., between establishing new bio-based processes and reflections on the limits of biomass utilization, should be deliberated on in collaboration. Furthermore, a framework for an integrated assessment of socially responsible research [37] should be introduced in the bioeconomy research area.

Supplementary Materials: Supplement S1: Questionnaire, available online at: http://www.mdpi.com/2071-1050/11/15/4253/s1.

Author Contributions: Conceptualization and methodology, C.P. and R.M.; survey execution and analysis, C.P.; writing—original draft preparation, C.P. and R.M.; writing—review and editing, C.P. and R.M.; visualization, C.P. and R.M.; project administration, R.M.; funding acquisition, C.P. and R.M..

Funding: This research was supported by the Ministry of Science, Research, and the Arts of Baden-Württemberg within the framework of the Bioeconomy Research Program Baden-Württemberg and is based on the project "Bioeconomy in Baden-Württemberg", grant number 33-7533-10-5/145/1.

Acknowledgments: We thank our retired colleague Juliane Jörissen for developing and conducting the survey with us and all of the scientists involved in the Bioeconomy Research Program Baden-Württemberg who filled out the questionnaire. We acknowledge support from the KIT-Publication Fund of the Karlsruhe Institute of Technology.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Food and Agriculture Organization of the United Nations (FAO). *How Sustainability Is Addressed in Official Bioeconomy Strategies at International, National and Regional Levels*; FAO: Rome, Italy, 2016.
2. Dieckhoff, P.; El-Chichakli, B.; Patermann, C. *Bioeconomy Policy. Synopsis and Analysis of Strategies in the G7*; German Bioeconomy Council: Berlin, Germany, 2015; Available online: https://biooekonomierat.de/fileadmin/Publikationen/berichte/BOER_Laenderstudie_1_.pdf (accessed on 18 June 2019).
3. Fund, C.; El-Chichakli, B.; Patermann, C.; Dieckhoff, P. *Bioeconomy Policy (Part II)*; Synopsis of National Strategies around the World; German Bioeconomy Council: Berlin, Germany, 2015; Available online: http://biooekonomierat.de/fileadmin/international/Bioeconomy-Policy_Part-II.pdf (accessed on 18 June 2019).
4. Fund, C.; El-Chichakli, B.; Patermann, C. *Bioeconomy Policy (Part III)*; Update Report of National Strategies around the World; German Bioeconomy Council: Berlin, Germany, 2018; Available online: http://biooekonomierat.de/fileadmin/Publikationen/berichte/GBS_2018_Bioeconomy-Strategies-around-the_World_Part-III.pdf (accessed on 18 June 2019).
5. Overbeek, G.; de Bakker, E.; Beekman, V.; Davies, S.; Kresiewa, Z.; Delbrück, S.; Ribeiro, B.; Soyanov, M.; Vale, M. *Review of Bioeconomy Strategies at Regional and National Level*; BioSTEP Project: Berlin, Germany, 2016; Available online: http://bio-step.eu/fileadmin/BioSTEP/Bio_documents/BioSTEP_D2.3_Review_of_strategies.pdf (accessed on 18 June 2019).
6. Mengal, P.; Wubbolts, M.; Zika, E.; Ruiz, A.; Brigitta, D.; Pieniadz, A.; Black, S. Bio-based Industries Joint Undertaking: The catalyst for sustainable bio-based economic growth in Europe. *New Biotechnol.* **2018**, *40*, 31–39. [CrossRef] [PubMed]
7. Meyer, R. Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates. *Sustainability* **2017**, *9*, 1031. [CrossRef]
8. Priefer, C.; Jörissen, J.; Frör, O. Pathways to Shape the Bioeconomy. *Resources* **2017**, *6*, 10. [CrossRef]
9. Staffas, L.; Gustavsson, M.; McCormick, K. Strategies and Policies for the Bioeconomy and Bio-Based Economy: An Analysis of Official National Approaches. *Sustainability* **2013**, *5*, 2751–2769. [CrossRef]
10. McCormick, K.; Kautto, N. The Bioeconomy in Europe: An Overview. *Sustainability* **2013**, *5*, 2589–2608. [CrossRef]
11. Bugge, M.M.; Hansen, T.; Klitkou, A. What Is the Bioeconomy? A Review of the Literature. *Sustainability* **2016**, *8*, 691. [CrossRef]
12. Hausknost, D.; Schriefl, E.; Lauk, C.; Kalt, G. A Transition to Which Bioeconomy? An Exploration of Diverging Techno-Political Choices. *Sustainability* **2017**, *9*, 669. [CrossRef]
13. Levidow, L.; Birch, K.; Papaioannou, T. Divergent Paradigms of European Agro-Food Innvoation: The Knowledge-Based Bio-Economy (KBBE) as an R&D Agenda. *Sci. Technol. Hum. Values* **2012**, *38*, 94–125.
14. Levidow, L.; Birch, K.; Papaioannou, T. EU agri-innovation policy: two contending visions of the bio-economy. *Crit. Policy Stud.* **2012**, *6*, 40–65. [CrossRef]
15. Schmid, O.; Padel, S.; Levidow, L. The Bio-Economy Concept and Knowledge Base in a Public Goods and Farmer Perspective. *Bio-Based Appl. Econ.* **2012**, *1*, 47–63.
16. Pfau, S.F.; Hagens, J.E.; Dankbaar, B.; Smits, A.J.M. Visions of Sustainability in Bioeconomy Research. *Sustainability* **2014**, *6*, 1222–1249. [CrossRef]
17. De Besi, M.; McCormick, K. Towards a Bioeconomy in Europe: National, Regional and Industrial Strategies. *Sustainability* **2015**, *7*, 10461–10478. [CrossRef]
18. Kircher, M. The transition to a bio-economy: emerging from the oil age. *Biofuels Bioprod. Biorefin.* **2012**, *6*, 369–375. [CrossRef]
19. Shortall, O.K.; Raman, S.; Millar, K. Are plants the new oil? Responsible innovation, biorefining and multipurpose agriculture. *Energy Policy* **2015**, *86*, 360–368. [CrossRef]
20. Hüsing, B.; Kulicke, M.; Wydra, S.; Stahlecker, T.; Aichinger, H.; Meyer, N. *Evaluation der „Nationalen Forschungsstrategie BioÖkonomie 2030". Wirksamkeit der Initiativen des BMBF—Erfolg der geförderten Vorhaben—Empfehlungen zur strategischen Weiterentwicklung*; Abschlussberich; Fraunhofer ISI: Karlsruhe, Germany, 2017.

21. Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg—Ministry for Science, Research, and the Arts of Baden-Württemberg. *Bioökonomie im System aufstellen. Konzept für eine baden-württembergische Forschungsstrategie „Bioökonomie"*; Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg: Stuttgart, Germany, 2013; Available online: https://www.baden-wuerttemberg.de/fileadmin/redaktion/dateien/PDF/Broschuere_Konzept-baden-wuerttembergische-Forschungsstrategie-Biooekonomie.pdf (accessed on 18 June 2019).
22. Mayring, P. *Qualitative Inhaltsanalyse. Grundlagen und Techniken*, 7th ed.; Deutscher Studien Verlag: Weinheim, Germany, 2000.
23. Organisation for Economic Cooperation and Development. *The Bioeconomy to 2030: Designing a Policy Agenda*; OECD Publishing: Paris, France, 2009.
24. Bundesministerium für Forschung und Bildung (BMBF)—German Ministry for Research and Education. *Nationale Forschungsstrategie Bioökonomie 2030. Unser Weg zu einer bio-basierten Wirtschaft*; BMBF: Berlin, Germany, 2010; Available online: https://www.bmbf.de/pub/Nationale_Forschungsstrategie_Biooekonomie_2030.pdf (accessed on 18 June 2019).
25. European Commission. *Innovating for Sustainable Growth: A Bioeconomy for Europe*; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions; European Commission: Brussels, Belgium, 2012.
26. Bundesministerium für Ernährung und Landwirtschaft—Federal Ministry of Food and Agriculture. *Nationale Politikstrategie Bioökonomie—Nachwachsende Ressourcen und biotechnologische Verfahren als Basis für Ernährung, Industrie und Energie*; BMEL: Berlin, Germany, 2014; Available online: https://www.bmbf.de/files/BioOekonomiestrategie.pdf (accessed on 18 June 2019).
27. Scordato, L.; Bugge, M.M.; Fevolden, A.M. Directionality across Diversity: Governing Contending Policy Rationales in the Transition towards the Bioeconomy. *Sustainability* **2017**, *9*, 206. [CrossRef]
28. European Commission. *Bio-Based Economy in Europe: State of Play and Future Potential—Part 2; Summary of the Position Papers Received in Response of the European Commission's Public On-Line Consultation*; European Commission: Brussels, Belgium, 2011; Available online: http://ec.europa.eu/research/consultations/bioeconomy/bio-based-economy-for-europe-part2.pdf (accessed on 18 June 2019).
29. Lösch, A. Technikfolgenabschätzung soziotechnischer Zukünfte. Ein Vorschlag zur wissenspolitischen Verortung des Vision Assessments. *TATuP* **2017**, *26*, 60–65. [CrossRef]
30. European Commission. *Review of the 2012 European Bioeconomy Strategy*; Directorate-General for Research and Innovation: Brussels, Belgium, 2017.
31. Levidow, L. European transitions towards a corporate environmental food regime: Agroecological incorportation or contestation? *J. Rural Stud.* **2015**, *40*, 76–89. [CrossRef]
32. Ramcilovic-Suominen, S.; Pülzl, H. Sustainable development—A 'selling point' of the emerging EU bioeconomy policy framework? *J. Clean. Prod.* **2018**, *172*, 4170–4180. [CrossRef]
33. Bennich, T.; Belyazid, S. The Route to Sustainability—Prospects and Challenges of the Bio-Based Economy. *Sustainability* **2017**, *9*, 887. [CrossRef]
34. Devaney, L.; Henchion, M.; Regan, A. Good Governance in the Bioeconomy. *EuroChoices* **2017**, *16*, 41–46. [CrossRef]
35. European Bioeconomy Stakeholders Panel. European Bioeconomy Stakeholders Manifesto. 2017. Available online: https://ec.europa.eu/research/bioeconomy/pdf/european_bioeconomy_stakeholders_manifesto.pdf (accessed on 18 June 2019).
36. Lescai, F.; Newton, A.; Carrez, D.; Carus, M.; Griffon, M.; Jilkova, J.; Juhász, A.; Lange, L.; Mavsar, R.; Pursula, T.; et al. *Expert Group Report—Review of the EU Bioeconomy Strategy and its Action Plan*; European Commission: Brussels, Belgium, 2017.
37. Daedlow, K.; Podhora, A.; Winkelmann, M.; Kopfmüller, J.; Walz, R.; Helming, K. Socially responsible research processes for sustainability transformation: an integrated assessment framework. *Curr. Opin. Environ. Sustain.* **2016**, *23*, 1–11. [CrossRef]