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Review

Priorities in Bioeconomy Strategies: A Systematic Literature Review

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Abstract: Bioeconomy is an emerging concept and no commonly accepted definition has been given so far. Bioeconomy strategies attempt to cover every aspect of this emerging concept from a different perspective, depending on the country, region, or organisation issuing them. For these reasons, each strategy has its own priority fields depending on the economic, geomorphological, social, ecological, and technological conditions of each country. In this review, an attempt is made to study the priority fields of bioeconomy strategies through a systematic review of the literature. PRISMA analysis was used to review the literature on the priority fields of bioeconomy strategies. The review examined the issue in the rich academic literature of two databases, Scopus and AgEcon. Using a repeatable search process to identify relevant studies in the literature, only 68 publications met the eligibility criteria that were included in the review. The results show that there are trends in the priority fields of bioeconomy strategies in the years 2013–2022. Moreover, the economic and technological development of the respective countries foreshadows their priorities. A successful transition to a bioeconomic model requires the participation of society as a whole, because a sustainable society as a whole requires sustainable and environmentally friendly solutions. The study concludes that governance with global coordination and stakeholder training is needed for successful implementation of bioeconomy strategies.

Keywords: bioeconomy strategies; bioeconomy priorities; systematic review of the literature; network visualization

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1. Introduction

The term bioeconomy seems to have been used already in the early 2000s [1], while policy discussions on the bioeconomy started in the middle of the decade on the agenda of the European Commission (EC). However, the foundations for the bioeconomy come from previous strategic agendas of the EC, including the 1993 white paper that emphasised the need for knowledge-based investment and the role of biotechnology in innovation and growth, and the Lisbon agenda in 2000, which called for global leadership to focus on the knowledge economy to ensure competitiveness and economic growth. In addition, in 2002, the EC stated that life sciences and biotechnology are probably the most promising cutting-edge technologies, with a high potential to contribute to the achievement of the Lisbon agenda objectives. In 2005, at the international conference of the European Union, the knowledge-based bio economy (KBBE) framework was presented, followed by another conference in 2007, which outlined the prospects for the European bioeconomy over the next 20 years. These two events contributed to the emergence of the knowledge-based bioeconomy in European policy circles [2].

Bioeconomy is of high attractiveness as a potential solution for green growth and competitiveness [3]. The European bioeconomy strategy supports the production of renewable biological resources and their conversion into vital products and bioenergy in order to meet the 2030 agenda and its sustainable development goals [4]. Biomass resources represent an opportunity for sustainable development in bio-based industries [5], covering

sectors as diverse as agriculture, food, biochemicals, bioenergy, biocides, and forests [6,7]. Moreover, the development of bioeconomy sectors represents an opportunity to promote innovation and job creation in rural and industrial areas [8]. It is also an opportunity to revitalise productivity and growth by improving the competitiveness of domestic industries through new technologies [9], and reducing dependence on imported raw materials by rehabilitating marginalised areas [10].

In the context of climate change, there is a need to make the production process and consumption patterns more sustainable, due to the increasing pressure on non-renewable resources. A shift towards more sustainable production and more efficient use and management of bio-resources can help reduce waste, pollution, climate change, and the use of fossil resources. This shift implies a series of changes in both primary production and industry processes that are characterised as bioeconomy [11].

Bioeconomy describes a concept that recognises the full potential of biotechnological research and innovation for the economy and society as a whole. It has been promoted over the last twenty years, particularly by the pioneering biotechnology countries such as The Netherlands, Germany, and Finland [12]. In 2006, the OECD had already presented a major report "The Bioeconomy 2030: Designing a policy agenda" [13]. In 2012, the European Commission presented the first bioeconomy strategy [14]. In this framework, the bioeconomy was defined as follows: "The bioeconomy involves the production of renewable resources and their transformation into food, feed, bio-products and bio-energy. It includes agriculture, forestry, fisheries, food and paper production as well as chemical and energy parts. The bioeconomy sectors are innovative as they use a wide range of sciences (life sciences, earth sciences, ecology, food science, social sciences) and technologies (biotechnology, nanotechnology, ICT), engineering and local traditional knowledge".

As expressed in the 2018 updated strategy, the EU's bioeconomy objectives are: (a) to ensure food and nutrition security, (b) to ensure the sustainability of the natural resources, (c) to reduce dependence on non-renewable, unsustainable resources whether sourced domestically or from abroad, (d) to mitigate and adapt to climate change, and (e) to strength European competitiveness and create jobs [4]. These objectives were revised to recognise the contribution of the bioeconomy strategy to both the circular economy and the Energy Union. The scope had to be adjusted and harmonised with European priorities [4].

Based on the above, it can be concluded that a strategy for the bioeconomy is a set of expectations. All bioeconomy strategies aim to contribute to the economic growth and international competitiveness of the respective economic system [15]. Moreover, job creation is explicitly expected in some strategies as a consequence of economic growth. Furthermore, strategies that define the bioeconomy in the broadest sense extend the promise of economic growth to traditional bioeconomy sectors [16]. Economic expectations are closely linked to the goal of the bioeconomy playing a leading role in technological development. Common to all strategy documents is the fact that new scientific findings and technological developments are shaping the bioeconomy and should be supported [17].

Almost all strategies expect the bioeconomy to make a significant contribution to society or global challenges. Food security, resource conservation, climate and environmental protection, and health problems are mentioned as examples. The scarcity of fossil resources and climate change are the business case for the intended transition from a fossil-fuel-based economy to a bio-based economy [17]. Strategies differ in the extent to which they envision the replacement of fossil resources with bio-based resources. This implies a transition from a bio-based economy with reduced dependence on fossil resources to an economy based on renewable resources [14]. At the same time, the disorganised nature of the bioeconomy is indicated as far-reaching, and the integrated process of social transformation must be supported by social, economic, political, and ecological research. From a transformation approach, some of the strategies face conflicts in objectives, side effects, and governance issues [18].

About half of the strategies predict that the bioeconomy will acquire a global character, with two different lines of argumentation: first, the bioeconomy is seen as part of a global

strategy for sustainable resource management and focuses on solving global challenges. The second argument sees the bioeconomy as a global phenomenon. Here, emphasis is placed on the global interconnection of biomass resources, value chains, and technologies, with an international division of labour in research, production, and markets [19]. Both arguments foresee crucial progress in health in the context of the bioeconomy. The purpose of developing bioeconomy strategies at the national level or internationally is common, as it revolves around sustainability and viability. Despite existing barriers and conflicts of interest [20], it is a one-way street to implement a bioeconomy strategy by all.

In the literature, although bioeconomy strategies are analysed in detail, it is clear that each one focuses on the specific priorities and needs of each country or region. There are no studies that address all of the priorities, and this is the gap that this review attempts to fill.

The main objective of this study is to review the relevant international scientific literature on existing bioeconomy strategies and their priority fields using a systematic review of the literature. In addition to the results of the research on bioeconomy strategies, the evolution of these topics, the relationships between them, and the policy measures taken are also examined. The importance of this study lies in the fact that several countries have not yet adopted bioeconomy strategies and they have an immediate obligation to do so by contributing to the global effort to save the planet. The next section presents the methodology followed, the results of the analysis, and finally the conclusions, limitations, and recommendations for future research.

2. Materials and Methods

A systematic review performs a critical role, since it can provide a synthesis of knowledge in a particular field. The knowledge generated guides future research priorities and helps to answer questions that individual studies could not answer. Still, systematic reviews contribute to primary research by identifying problems that need to be corrected in future studies, and evaluate theories about how or why certain phenomena occur [21]. As a systematic review can be used by a variety of users such as citizens, researchers, and policy makers, it must be transparent, comprehensive, and accurate [22]. PRISMA analysis serves the above purpose, and is designed to address the underreporting of systematic reviews [23]. Specifically, PRISMA analysis includes a checklist of 27 items [21] that are widely adopted, and adopted as evidenced by the citation of more than 31,000 documents in Scopus alone (August 2022). Although numerous studies report that PRISMA analysis is associated with more complete reporting of systematic reviews [24–27], there is a counter argument that corrective actions could be taken to improve it [28].

In this study, PRISMA analysis was used to review the literature on the priority fields of bioeconomy strategies. Although the research on priority fields individually (climate change, economic development, pollution reduction, energy, employment, etc.) is systematic and standardised, it is not in all cases linked to the bioeconomy strategies implemented by countries. In addition, the VOSviewer was used for the bibliometric analysis. This software has key advantages such as being reliable and widely accepted, has been used in similar studies, and is open source and freely accessible.

The data for the study were obtained from the Scopus and AgEcon databases. In the literature there are numerous systematic reviews on the broader concept of bioeconomy, mainly in the Scopus, Web of Science, and AgEcon databases [29–34]. Due to lack of access, Web of Science was excluded from this study. The aforementioned databases allow the user to extract data including journal articles, reviews, book chapters, conference proceedings, books, short surveys, notes, and data paper. Mention of priority fields in bioeconomy strategies is made in national or regional frameworks, but they were not included in this study because these documents were not included in the databases from which data were extracted. Moreover, these studies were often not written in English [35].

The search for publications related to the priority fields in bioeconomy strategies was carried out in the “title, abstract, keywords” field of the databases. In the first stage, the set of publications from both databases (Scopus, AgEcon) was selected without setting any

time specification, and then the publications relevant to this study were manually selected after removing duplicates and non-English publications (Figure 1).

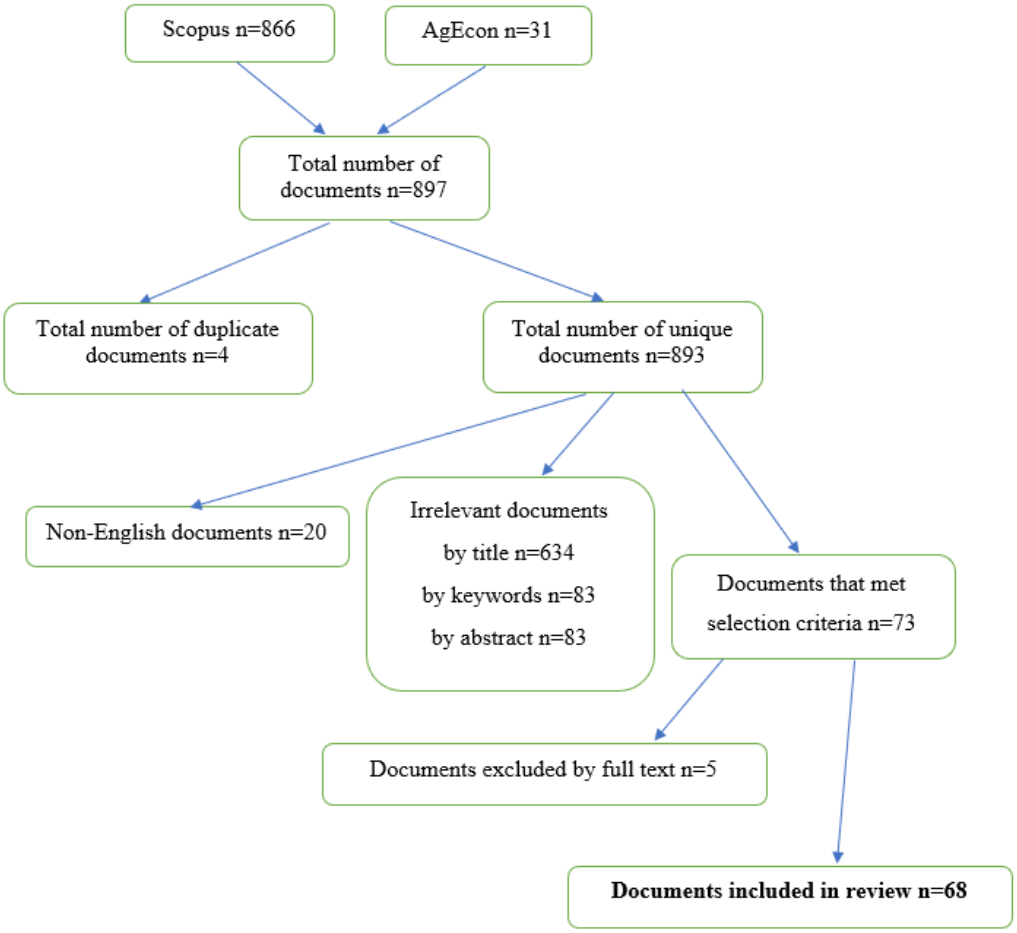


Figure 1. Flow diagram describing study selection. Source: authors' elaboration.

To determine the most appropriate search term, several test searches with different terms were performed [36]. The search to identify the articles started with the term (bio* OR bio-* OR bio-based* OR biobased* OR biobased*) AND (economy) AND (strategies) in the TITLE-ABS-KEY field, and yielded 5335 results (5241 Scopus, 94 AgEcon) on 25 August 2022. However, it was noted that the term bio-based or biobased was not directly associated with bioeconomy strategies, but with products or sectors, and was removed [37–40]. The search was designed to be repeatable, i.e., research that did not meet certain criteria was removed [41]. To minimise the risk of omitting relevant work, additional test searches were conducted by alternating combinations of terms. It was realised that the term bio-economy was largely associated with the circular economy and was also removed [42–45]. In the final search, which was adopted in this review, the terms "bioeconomy" AND "strategies" returned 897 results (866 Scopus, 31 AgEcon). Then, non-relevant publications were manually removed after reading the titles, keywords, abstracts and, if necessary, the full text. Finally, 68 publications remained, which were used as the basis for this review.

In reviewing the publications that met the selection criteria, a number of issues arose. Firstly, the strategy in some publications was not identified by its explicit name, but by terms such as policy [46–48], programme [49], or pathway [50,51]. Another difficulty is that some strategies referred to priority fields that were already being implemented, while others referred to future implementation of the priority fields and what their impact would be [52–56]. Only those studies that explicitly referred to strategies already being implemented were included in this study.

3. Results

The selection process of the publications included in the review is shown in Figure 1. The initial search of the two databases yielded 897 results and in order to remove duplicates, the title of the publication was used as a criterion. Consequently, 893 publications were identified as unique and 73 of these, based on the manual search, met the relevance criteria (i.e., no irrelevant titles, keywords, abstracts) and were written in English. In the case of 11 publications, it was deemed necessary to read the whole article to decide whether to include them in the review, resulting in 6 of them being included and 5 publications that referred to future actions being rejected. In summary, a total of 68 publications are examined in this review.

3.1. Bibliometric Analysis of Country Strategies and Journals

Analysing the publications with the VOSviewer software [57], it is clear that they come from 39 countries, with Germany leading in the studies on bioeconomy strategies (Figure 2). In addition, 53.8% of these countries are European. Sustainability (Switzerland) is the most frequently appearing journal in the review with 15 publications, followed by New Biotechnology with 7 publications. In total, 68 publications are distributed across 41 journals (Figure 3).

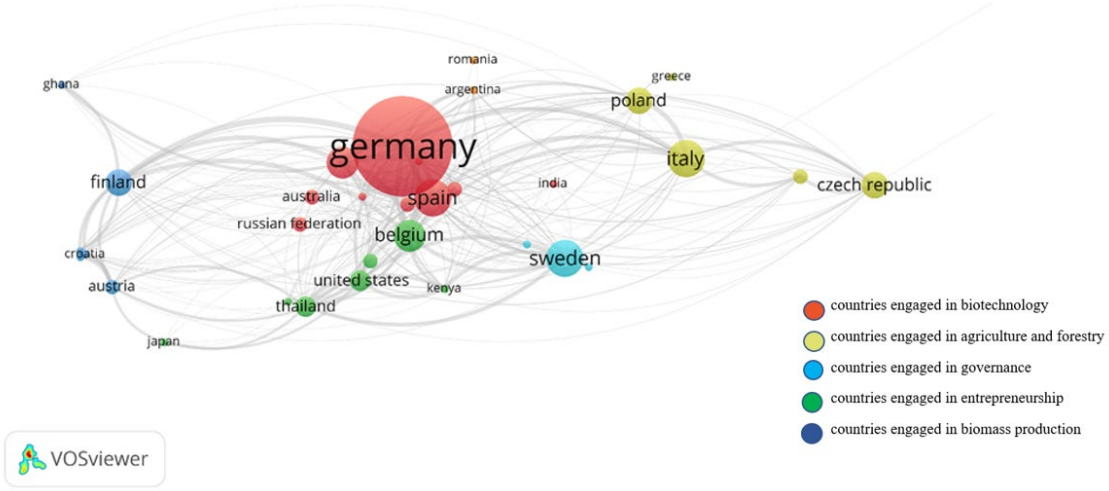


Figure 2. Co-authorship analysis/countries. Source: VOSviewer output.

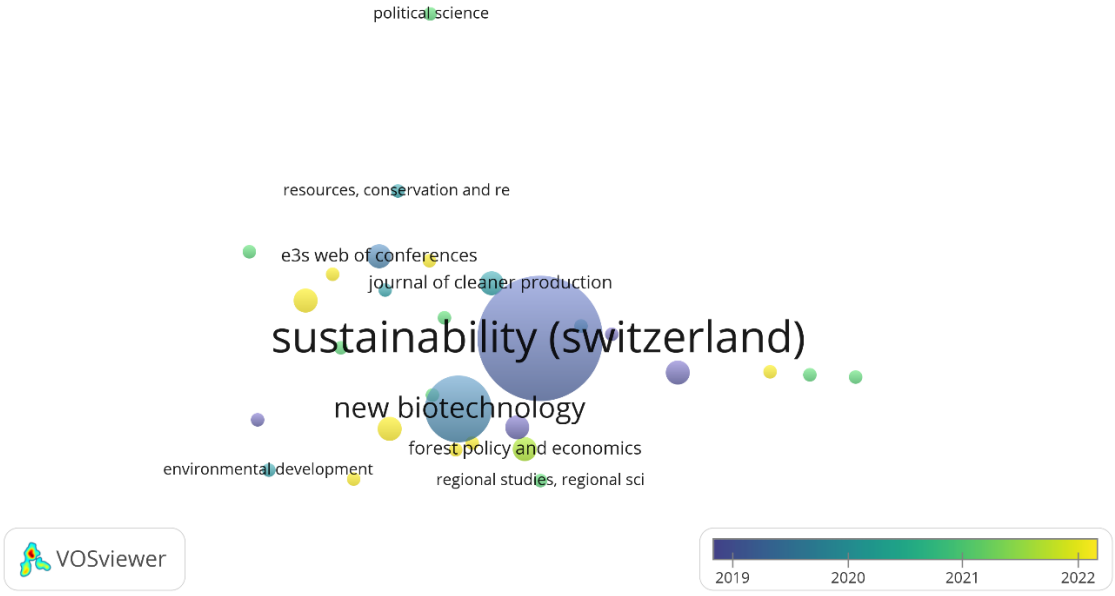


Figure 3. Bibliometric coupling analysis/sources. Source: VOSviewer output.

The colours in Figure 2 indicate the countries' priorities regarding their bioeconomy strategies. Each cluster colour is described in detail below. The bioeconomy strategies of the red cluster countries promote biotechnology, technological development, and innovation in renewable resources as a priority axis [58–61]. These countries are investing in biomass value chains and bioenergy through biofuels [19,62,63]. Yellow cluster countries promote the development of the bioeconomy through agriculture [64,65] and forestry [48,66], believing that economic growth comes through proper resource management and gross added value from biomass production [67,68]. Competitiveness and employment are also priorities for these countries [69]. The light blue cluster countries consider governance and knowledge transfer of utmost importance for a successful bioeconomy strategy [46,70]. As they also have a more ecological vision, their priority axis is climate change mitigation and sustainability [71,72]. Entrepreneurship and business models are the priorities of the green cluster countries [73–75]. Through these, economic growth, pollution reduction, and proper management of resources will be achieved [47,76]. Finally, the blue cluster countries have the exclusive priority of biomass production. Countries such as Finland, Serbia, Croatia, and Austria base a large proportion of their economies and trade on biomass production [77–79].

Journals belonging to the dark cluster have been publishing on bioeconomy strategies since 2019, as seen in the legend in Figure 3. In contrast, journals shown in green or yellow have only been working on bioeconomy strategies in the last two years.

3.2. Overview of Priority Fields by Year, Author, and Geographical Area Covered

Priority fields were examined in terms of how many times they appear in publications per year (Figure 4). In orange, priority fields appear once per year; in yellow, twice; in blue, three times; in purple, four times; in brown, five times; and in green, six times. It is clear that there is a shifting trend, i.e., from an insistence on biotechnology to a more environmentally friendly technological development. According to Spies et al. [58], technology has a central role in bioeconomy policies, but there are barriers to integrating its approaches due to the lack of ecological considerations, appropriate management of natural resources, and maximising positive interactions between decision makers, local communities, and nature. Biomass production is a priority over time. Biomass is related to plants, animals, their derivatives, and organic waste [80]. The transformation of this biomass into biomaterials is an innovation, and contributes to resource sufficiency and waste management [81]. Moreover, the economic use of biomass is a priority for the development of the bioeconomy [48].

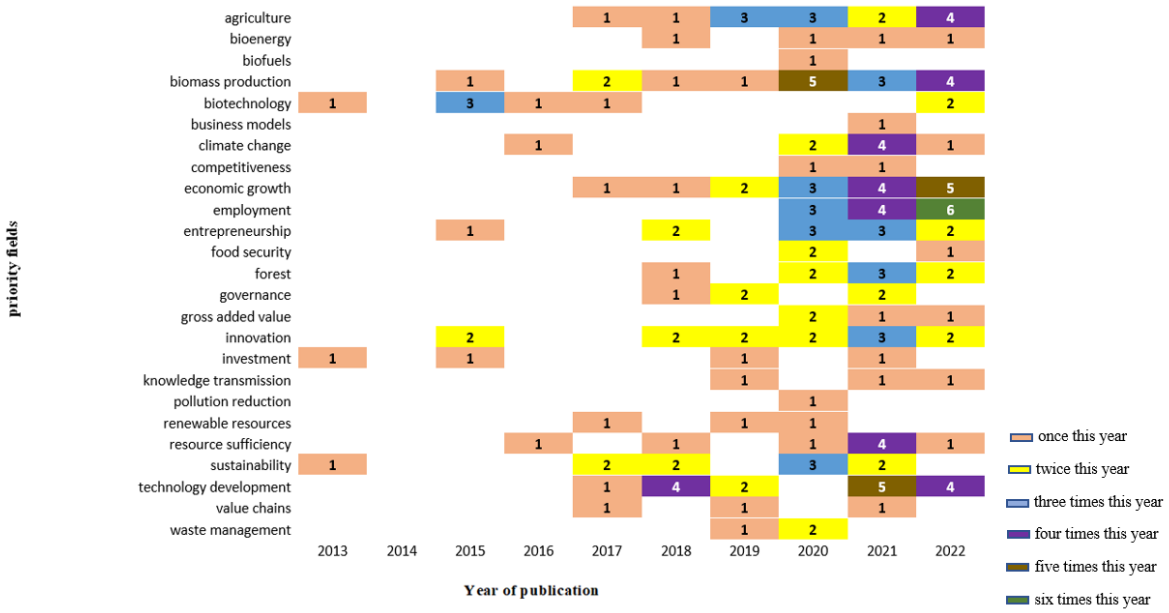


Figure 4. Number of documents including priority fields per year of publication. Source: authors' elaboration.

Three priority fields that can be considered highly relevant for the three-year period of 2020–2022 are economic growth, employment, and entrepreneurship. Economic growth from the implementation of bioeconomy strategies comes from value addition (among others) in agriculture, forestry, and food industry [82]. In the European Union, two thirds of the people employed in the bioeconomy come from the agricultural sector, despite the decrease observed due to the agricultural sector restructuring in 2015–2017, and 2 million employees leaving the sector [83]. Agriculture, forestry, and the food industry contribute about 24–26% of total labour productivity in the bioeconomy (excluding services), and play an important role in its development [82]. Still, critical issues such as urbanization and migration of populations to urban centres or abroad, causing desertification of the rural areas, can be controlled through employment in the bioeconomy [84]. Regarding the role of entrepreneurship in the bioeconomy and sustainable development, it is shown to create opportunities for the production of goods and services that provide economic and non-economic benefits, all while preserving the natural and social environment [85]. Entrepreneurship, in addition to increasing employment [86], has the potential to address market failures in terms of environmental issues and to respond to sustainability challenges with different strategies [85]. It is clear, on the basis of the above, that the market idea that economic growth mitigates inequalities is rejected [87]. Economic development through the bioeconomy contributes to social cohesion and focuses on equity for people who are marginalised because they may belong to specific incomes, regional, or labour groups.

In Figure 4, it is notable that the documents are published after 2013. This is due to the inclusion of only documents included in the Scopus and AgEcon databases. This explains the omission of the 2012 European bioeconomy strategy [14].

Priority fields in bioeconomy strategies were assigned to each publication according to the authors' description. Some authors focus on resource sufficiency, but also on the added value to be derived from the use of agricultural, livestock, forestry, and organic biomass [46,48,50,58,61,64–66,74,75,77,79,80,84,87–93]. In essence, these are countries or regions with a developed primary sector and the capacity to invest in biomass value chains while achieving environmental and social benefits. Another group of authors focus on technology development and innovation, for the exploitation of renewable resources or waste management [30,31,68,94–103]. Their aim is to achieve sustainability and decoupling from fossil resources. Subsequently, a fairly significant number of papers consider governance as a priority of the bioeconomy [51,78,104–106]. These authors very aptly understood that, in addition to the adoption of a bioeconomy strategy, whether societies can adapt to new rules and challenges is of major importance. They conclude that global coordination of governance is needed [105]. Finally, the employment and entrepreneurship fields are identified as drivers of economic growth and competitiveness by numerous authors [60,63,69,73,82,83,83,107]. These authors argue that policy makers should take into account the core of entrepreneurial transformation as it takes shape in universities and research centres [63]. The knowledge generated in these centres is the starting point for bioeconomy strategies and the competitiveness of countries [69].

The priority fields of the bioeconomy strategies are most frequently examined at the national level (29 publications) and the majority of them are affiliations of European countries, mainly from central Europe and the Nordic Peninsula (Appendix A, Table A1). At the same time, 14 publications present bioeconomy strategies in the European Union as a whole, 13 publications present bioeconomy at the global level, 11 publications present priority fields applied at the regional level, and 1 publication presents how a bioeconomy strategy can be implemented in a company and what its priorities are. It is concluded that the geographical coverage is extensive.

4. Discussion and Conclusions

The purpose of this systematic review was to identify priority fields for bioeconomy strategies in order to contribute to a more evidence-based dialogue on the actions and policies to be implemented in the future.

The global economy, due to its heavy dependence on fossil resources, including oil, as an energy source, is vulnerable to the declining supply and volatile market for these resources [108]. Therefore, in order to secure the economy, countries need to become low-carbon and resource-efficient societies based on bio-based products. The development of the bioeconomy affects many sectors and branches of the economy, so countries are adopting strategies and taking measures. The bioeconomy contributes to food security, sustainable management of natural resources, improved waste management, reduced dependence on non-renewable resources, mitigation of climate change, job creation, and maintaining competitiveness [109]. Bioeconomy strategies address the changes, inter alia, by developing knowledge in the areas of primary production and food production [110]. By implementing bioeconomy strategies and related initiatives, it is more manageable to reduce waste and increase the efficiency of the food chain with changes, particularly in developed countries [92].

Sustainable production includes the use of biotechnology and other modern technologies that allow for increasing productivity and efficiency, reducing environmental impacts, the development of sectors such as biofuels, and the production of biomaterials from agriculture, forestry, and the domestic sector [62]. In the context of climate change, agriculture can be seen as an ally. The development of the bioeconomy in the sector can help reduce CO_2 emissions by reducing energy consumption [4]. The implementation of bioeconomy strategies also contributes to the sustainable management of natural resources. The development of agriculture, forestry, and livestock is linked to the resources needed for biomass production [89]. These resources are finite and depleting, so it is necessary to adopt an approach to production that can be described as 'more biomass from fewer resources'. In this context, the development of the bioeconomy should lead to a better use of nature's self-regulating functions that allow a better understanding of the functioning of ecosystems. Significant growth is also coming from sustainable primary production and the development of biotechnology, leading to the transformation of existing, and the opening of new, markets for bioproducts [111]. These developments are increasing the demand for labour in the primary sector and industry.

At the same time, mitigating the effects climate change, while ensuring energy security and economic growth and prosperity is a huge challenge. Turning vision into reality requires knowledge-based innovation and research [47]. Supporting innovation is a driving force and this conviction stems from the challenges facing the world today, such as sustainable management of natural resources, sustainable production, improving public health, mitigating climate change, inclusive social development, and global sustainability.

Despite the dominant focus on sustainability, the primary sector, technology development, and biomass production, this review shows that bioeconomy strategies are influenced by government policy, existing regulations, and human resources, as well as social acceptance and market structure. If there is no governance coordination, no strategy can be implemented [94,106]. These factors interact with each other, modifying the influence of each separately. A successful transition to a bioeconomic model requires the participation of society as a whole, because a sustainable society as a whole requires sustainable and environmentally friendly solutions. The search for opportunities to accelerate the development of regions and countries requires linking the concept of sustainable development to a more flexible use of resources through better application of knowledge and innovation, and the development of more efficient technologies. The implementation of bioeconomy strategies in a region's development policy must be the result of a conscious decision by state and local authorities, and their ability to coordinate and create an effective network of cooperation between scientific, economic, business, and local stakeholders [78,112].

Three key findings of this review are:

- There is no mention in any paper of bioeconomy education for stakeholders (farmers, entrepreneurs, etc.). Knowledge generated from research needs to be channelled to society to facilitate acceptance and adoption;

- The bioeconomy business models and clusters already successfully developed in China [113] contribute to the exclusion and marginalisation of small and regionally isolated producers;
- The current energy crisis demonstrates the dependence of countries on carbon and the weakness of bioeconomy strategies in solving the major problem.

As the priority fields of bioeconomy strategies "lose" their ecological focus and acquire a social, and at the same time capitalist, vision, priorities now focus on economic growth, gross value added, entrepreneurship, competitiveness, employment, and technology development, and future research is suggested to avoid some of the previous trends such as the focus on biodiversity, the development of remote regions, and agro-ecological systems. It is also important to carry out future research on the training of bioeconomy participants, and to include education as a priority in strategies.

In conclusion, limitations identified in this review are the omission of relevant publications (e.g., bioeconomy strategies) that are excluded as they are not included in the databases used. Also, the grey literature and studies that are not written in English are not included. As a measure of quality, peer-reviewed studies are distinguished from other studies, and this aspect is taken into account when summarising the conflicting results of the studies.

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Appendix A

Table A1. Overview of publications by unit of analysis and country of affiliation.

Unit of Analysis	Publication Number in References List	Country of Affiliation
Nation	[66]	Czech Republic
	[84]	Norway, Denmark, Canada, Nepal
	[59]	Germany
	[88]	Argentina, Germany
	[85]	Poland
	[89]	Germany, Finland, Ghana
	[114]	Canada
	[71]	Sweden
	[68]	Brazil
	[115]	Germany
	[69]	Italy
	[95]	Czech Republic
	[73]	Latvia
	[106]	New Zealand
	[75]	Thailand, China
	[81]	Bulgaria
	[48]	Czech Republic
	[116]	Czech Republic, Brazil, Italy
	[92]	India
	[104]	New Zealand
	[93]	Greece, Poland
	[64]	Poland
	[101]	Spain

Table A1. *Cont.*

Unit of Analysis	Publication Number in References List	Country of Affiliation
Nation	[117]	Australia
	[103]	Germany, Italy
	[118]	Netherlands
	[49]	Australia
	[119]	Sweden
	[72]	Sweden
EU	[82]	Spain
	[83]	Spain
	[87]	Germany
	[60]	Germany
	[47]	Germany, Belgium, Netherlands, Finland
	[62]	Germany
	[90]	United Kingdom
	[97]	Italy, Spain, Belgium
	[109]	Germany
	[98]	Germany
	[107]	Poland
	[100]	Germany
	[102]	Germany, Belgium
	[19]	Germany
International	[46]	France
	[58]	Germany
	[50]	Sweden, Belgium, Kenya, Thailand, USA
	[31]	Italy
	[94]	Ukraine
	[67]	Italy
	[74]	USA
	[51]	Sweden
	[80]	Spain
	[70]	Netherlands
	[63]	Germany
	[61]	Germany
	[105]	Germany
Region	[77]	Finland, Croatia, Serbia, Austria
	[110]	Colombia
	[96]	Sweden, Costa Rica
	[91]	Russia
	[65]	Poland
	[99]	Russia
	[30]	Spain
	[78]	Finland
	[120]	Romania
	[79]	Austria, USA
	[121]	Australia
Company	[76]	Latvia

Source: Authors' elaboration.

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