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# Bioeconomy—Spatial Requirements for Sustainable Development

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**Abstract:** The implementation of the bioeconomy, i.e., the conversion of an economic system from fossil to biogenic, renewable resources, is seen as an important component of sustainable development by many bioeconomy strategies. What has hardly been taken into account and investigated are the spatial requirements for a sustainable transition to this new system. In order to clarify this, bioeconomy related strategies and policy papers were analyzed thematically. It was shown that spatially relevant issues are addressed to very different extents. Some strategies have a clear technological and economic orientation, while other documents point to the importance of the regional and local levels and the use of spatial planning measures to successfully and sustainably implement a bioeconomy. Overall, the picture emerged that many strategies are still a long way from mainstreaming Sustainable Development Goals (SDGs), as set out by the United Nations.

**Keywords:** bioeconomy; strategy; policy; sustainability; sustainable development; SDG; regional development; spatial planning; Boyatzis; qualitative content analysis

## 1. Introduction

The bioeconomy aims at the transition of economy and society from a fossil to a renewable resource base [1] (p. 1). As mankind lives in a resource garden in which each individual has his/her share related to lifestyle and economic practices [2], the bioeconomy will inevitably increase pressures on arable land for the production of feed, food, fiber and fuel. As a consequence, this conversion to the use of renewable raw materials will intensify existing and open up new land use conflicts [3]. These related conflicts have to be addressed. Spatial planning may offer important contributions, on the one hand, to enable government control of the spatial demands of the bioeconomy and, on the other, to secure land for the production of biological raw material.

To avoid negative consequences of the implementation of a bioeconomy, spatial planning offers five main strategies:

1. Land saving development: the development of compact settlement structures protects agricultural production areas. Compact settlements are based on planning principles like mixtures of functions, adequate density, nearness, development within settlement borders and the reuse of abandoned building land [3].
2. Zoning agricultural priority areas: different planning systems make it possible to establish priority areas for agricultural land that are to be kept free of building and infrastructure development [4].
3. Zoning ecological priority areas: The centralized, intensive production of agricultural raw materials leads, for example, to monotonous landscapes with large monocultures and few ecologically relevant landscape elements, which, in turn, lead to a loss of biodiversity and other negative outcomes. Therefore, cultural landscapes with a high amount of landscape elements can be protected in order to prevent further loss [5].

4. Optimization of resource use: The spatial organization of the bioeconomy determines the resource intensity of production processes. For instance, a decentralized organization of the bioeconomy allows for the short-distance closure of material flows between agricultural production sites and processing sites, and saves related transport demands, emissions and infrastructure [6]. Moreover, the location of processing sites determines the possibilities of utilizing byproducts, e.g., waste-heat in district heating systems, which means that processing has to take place in or close to towns or cities. Furthermore, spatial organization might lead to the security or creation of jobs, especially in rural areas [3]. This is where a social dimension comes into play. Spatial planning can provide spatial preconditions to level out regional disparities and create livable conditions in rural areas.
5. Planning processes: Bioeconomy transformation needs clear visions and a well-defined value base. Spatial planning can provide participatory processes to negotiate the value base for the bioeconomy transition, especially how much land shall be devoted to food, feed, fiber or fuel generation, and how related land use conflicts should be solved [7]. Spatial planning processes might also offer effective participatory involvement of relevant stakeholders, civil society and the general public [3].

Spatial planning, with its systemic and cross-sectorial approach that is aimed at balancing spatial aspects and land use demands of environmental, social and economic development [8], can support the transition to a bioeconomy, also in line with sustainable development as framed in the Sustainable Development Goals (SDGs) [9]. Markard et al. describe this sustainability transition as a "long-term, multidimensional, and fundamental transformation process through which established socio-technical systems shift to more sustainable modes of production and consumption" [10] (p. 956). Spatial planning can bring in the spatial dimensions in decision-making concerning this transition related to renewable material production and energy generation. A bioeconomy, in turn, has the potential to be a building block in the implementation of sustainable spatial planning. Against this background, and because this paper is embedded in spatial planning science, this article aims to discuss the spatial dimensions of the bioeconomy and their consideration in related bioeconomy strategies.

For about a decade, the notion of the bioeconomy has been gaining increasing importance, both at the political and economic levels and as a research topic. This can be seen in the development of regional, national and transnational political bioeconomy strategies on the one hand, and in the increasing amount of scientific articles and international research projects on this topic on the other [11] (p. 2756). Bugge, Hansen and Klitkou [12] propose that the main focus of the scientific discourse is on the field of biotechnology and applied microbiology, followed by energy and fuel, and environmental sciences (p. 8). This broad scope of topics is also related to the different definitions of the bioeconomy. The OECD [13], for example, defines bioeconomy "as a world where biotechnology contributes to a significant share of economic output." This is a quite narrow view, focusing solely on technological and economical aspects. McCormick and Kautto [14] (p. 2590) speak of an economy "where the basic building blocks for materials, chemicals and energy are derived from renewable biological resources, such as plant and animal sources" and, thus, call for a holistic, integrative approach. Meyer comes to a similar conclusion in his analysis of some of the strategies that are also discussed here (EU/2012, Germany, OECD, Sweden and USA) [15]. The scientific discourse subsequently addresses the question of whether this transition is possible in a sustainable way, and what framework conditions are necessary to achieve this.

In their metastudy on sustainability in research on bioeconomy, Pfau et al. [16] show that the scientific discourse also deals with the negative effects of the changing use of natural resources by the implementation of a bioeconomy. Among the most important topics are "food security" (see for example [17]), "competition for land" and "land use change". De Besi and McCormick present additional focal points in their study on twelve bioeconomy strategies [18]. They propose that all these strategies aim at the best possible use of natural resources. This should be ensured by cascading their usage and by including waste and agricultural residues (p. 10467); however, in the analyzed strategies,

also competition on land use is addressed. In response to this challenge, the import of biomass from non-European production countries is proposed (p. 10469). In this context, it is stressed that production in the countries of origin must also be sustainable. However, the aspect of inevitably long transport distances (i.e., Africa to Europe) is not taken into account. Since transport will be based on fossil fuels in the foreseeable future, the positive effects of the usage of renewable raw materials will very quickly be diminished or even reversed [6].

Both metastudies [16,18] also emphasize the importance of the regional level for the successful development and implementation of the bioeconomy. Pfau et al. [16] point, among other issues, to the aspect of short distances and low transport costs due to local and decentralized production and processing, in order to illustrate the advantages of implementing the bioeconomy at the regional level. At the same time, this enhances economic development in rural areas and enables adaptation to regional characteristics and the production of agricultural raw materials appropriate to the area's environmental limits (p. 1237).

De Besi and McCormick [18] also refer to the importance of the regional level in promoting innovation and strengthening existing potentials (p. 10466). They also underline that the regional level of the bioeconomy is not in the focus of national strategies (p. 10474). In their article, Ramcilovic-Suominen and Pülzl stress aspects of sustainability in the EU bioeconomy policy [19], i.e., that it is primarily focused on issues such as production, economics and technology. Referring to the Brundtland Report [20], they conclude that the approach should be more comprehensive and take social and environmental issues into account. In order to achieve a balance between these three pillars (economic, social and environmental dimension), effective policy instruments would need to be put in place (p. 9). The implementation of the spatial planning strategies mentioned above could effectively support this policy making.

The Brundtland Report was one of the starting points for the preparation of the SDGs of the United Nations [9], which are intended to meet the global challenges on a broad basis of 17 goals and 169 targets. The European Spatial Development Perspective (ESDP) [21] is based on the same foundations, i.e., Society, Economy and Environment. In concrete terms, it is about economic and social cohesion, conservation of natural resources and cultural heritage and more balanced competitiveness of the European territory. This position is also supported by a study on the perception of bioeconomy among the Austrian population. Stern et al. [22] show that especially farmers and workers, i.e., those responsible for the production, are expecting negative effects from the transition to the bioeconomy. These social groups must therefore be given more consideration in future policies and be better integrated in planning processes if a bioeconomy is to be successfully implemented.

Gawel et al. [23] go one step further. They consider the bioeconomy to be impossible without sustainability, and also stress the equivalence of its economic, ecological and social dimensions. Using bioenergy as an example, they refer to the sustainability conflicts that can arise from the increased demand for biomass. In this context, they mention direct and indirect land use change and the increasing pressure on limited land resources (p. 7+24). Haberl et al. conclude in their studies on the global human appropriation of net primary production (HANPP) [24] that, for example, a comprehensive use of renewable raw materials in fuels can lead to increased pressure on ecosystems. In this context, land-use change is identified as an essential part of HANPP that can also influence ecosystem services on a global scale (pp. 12943–12945).

In its report on official strategies [25], the Food and Agriculture Organization of the United Nations (FAO) stresses the cross-cutting nature of the bioeconomy and the importance of its sustainable orientation due to its potential impact (p. 3). The FAO also notes that issues like land use changes, competition for land, building or transport are rarely mentioned. It also states that energy security is not addressed in the analyzed documents, although this may be an essential factor for the successful development of bioeconomy, as there may be strong competition for renewable raw materials. The FAO further points to the possible competition between locations for the construction of biorefineries (p. 12), as referred to in the German policy strategy [26].

The previous statements show that in the scientific discourse, different spatially related topics are addressed and regarded as essential for a sustainable transition towards a bioeconomy. Therefore, it can be deduced that certain spatial requirements have to be taken into account for a sustainable implementation of the bioeconomy. This has already been confirmed for integrated spatial and energy planning as a subarea of the bioeconomy [3].

Starting from this point of departure, several research questions arise around the spatial dimensions of a regional and decentralized bioeconomy:

1. How is the spatial dimension reflected in national and transnational strategies, and which relevant terms can be identified?
2. How are the five aforementioned spatial planning strategies reflected in the policy papers?

This set of questions was the starting point for this paper and for the selection of the necessary analytical methods, which are described in the following section. Question 1 is answered in the results section, and question 2 is examined in the discussion section of this paper.

## 2. Materials and Methods

### *2.1. Selection of Strategies*

The selection criterion for the strategies and policy papers to be analyzed was the per capita Gross Domestic Product (GDP, nominal) rank of countries between 1 and 50, based on the "Report for selected Countries and Subjects" of the International Monetary Fund (IMF) [27]. This is to ensure that enough strategies to be analyzed could be found and that the countries involved had a comparable level of economic development. The 50 countries were cross-checked with the three-part report of the German Bioeconomy Council on national strategies [28–30]. Then, countries were added that were not yet included in part III because they were published later (2018 and 2019). All publications up to 31 August, 2019 have been considered. This resulted in a list of 17 national strategies: 14 from EU member states and three from outside. In addition, the available transnational strategies were analyzed (OECD form 2009 [13] and EU from 2012 and 2018 [31,32]). This provided a sufficiently large sample of 20 strategies and policy papers for the analyses. The documents ranged from 8 to 107 pages (see Appendix A Table A1). The analysis of the policy papers shows that quantity does not necessarily correlate with quality in relation to spatial planning (see Section 3).

Within the EU, national strategies from 12 different countries were identified. It should be noted that Germany is the only country to have developed a research strategy [33], i.e., in 2010 in preparation for the political one in 2014 [26]. For France, in addition to the strategy [34], the separately available action plan [35] was also taken into account, which often forms an integral component in other countries' strategies (see Appendix A Table A1, column "Measures/Actions/Initiatives"). In addition to the documents from Germany and France, comprehensive bioeconomy strategies from nine other EU member states were examined, in alphabetical order according to the ISO-3166-1 alpha2 codes [36]: Austria (AT) [37], Germany (DE) [26,33], Denmark (DK) [38], Spain (ES) [39], Finland (FI) [40], France (FR) [34,35], United Kingdom (GB) [41], Ireland (IE) [42], Italy (IT) [43], Latvia (LV) [44], The Netherlands (NL) [45] and Sweden (SE) [46] See also Appendix A Table A1. Outside the European Union, Canada [47], Norway [48] and the USA [49] are the only countries that fit the selection criterion. As expected, all G7 countries [50] are included in the selection, except Japan. This country focuses on subsectors such as biomass [51], and has no national bioeconomy strategy. Apart from the standardized selection criteria, the policy papers differ in their orientation. Some are comprehensive frameworks (EC, OECD), while others are position papers (NL) with a research focus (DE, SE) or a technological-industrial orientation (GB, CA, USA).

The EU and its member states have been grouped above because they have a common objective in the commitment to sustainability derived from the "Commission's proposal to the Gothenburg European Council" (Gothenburg Protocol) 2001 [52] and the "Lisbon Treaty" 2007 [53]. By including

the OECD, Canada, Norway and the USA in the analysis, it should be clarified whether a similar sustainability orientation of their bioeconomy policies outside the EU-frameworks can be derived, or whether different approaches can be identified.

### 2.2. Process of Coding

A comprehensive analysis of spatial interrelations in bioeconomy strategies was carried out, taking two spatial levels into account: transnational and national strategies. The strategies to be analyzed were downloaded from the respective official websites to make sure that original documents were obtained. A qualitative content analysis according to the methods developed by Boyatzis 1998 [54] was performed in order to make the coding of text passages with spatial references visible within the strategies. The method had to be adapted to the needs of this project (see Figure 1). Based on the data driven inductive approach two categories, i.e., "strategy" and "no strategy", were defined, and the criterion "spatial reference or coherence" was determined. So, each strategy of the same level (the transnational and the national subsample) was set as the unit of analysis. The complete strategic paper was specified as the context unit, and the code units were the terms and text passages with spatial interrelations.

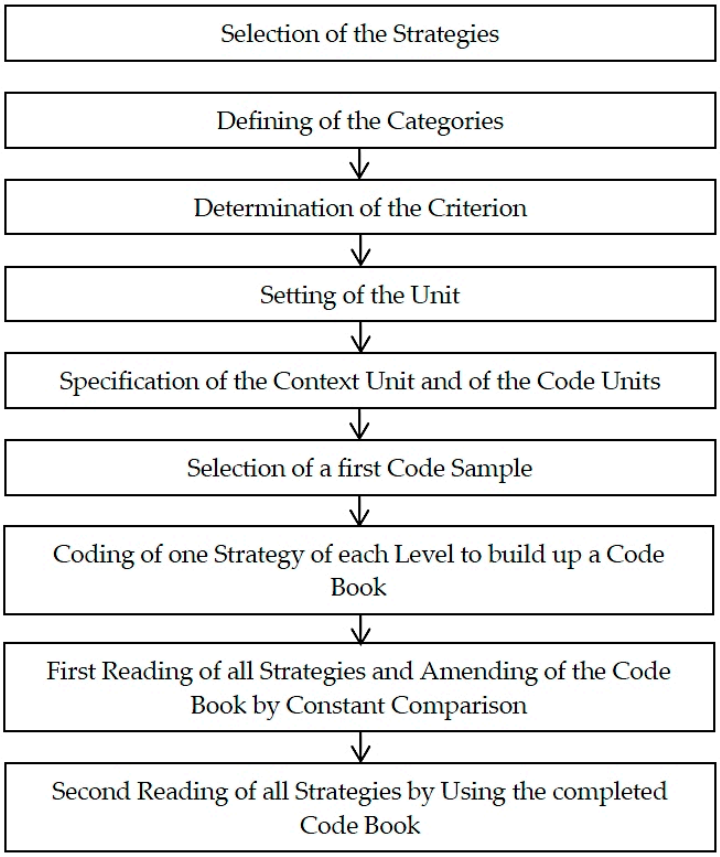


**Figure 1.** Process of Coding according to Boyatzis 1998.

The next step was the selection of a first sample of spatial codes. For this, standard terms from spatial planning were used, such as those found in Stöglehner 2019 [55]. These were supplemented by other terms from the literature e.g., Pfau et al. 2014 [16]. This resulted in a wide range of topics for the first list of codes:

- Competition for land
- Land availability

- Land use planning
- Land use change
- Local use
- Local reuse
- Regional planning
- Regional scale
- Rural development
- Spatial
- Spatial planning
- Spatial development
- Transportation costs

One strategy of each level [31,46] was coded on this basis to provide a comprehensive list at the beginning of the analysis. This list comprised a total of 56 codes with spatial interrelations that was used to build up a code book and a master table that was amended during the reading of the strategies. This is based on the method of constant comparison in the qualitative analysis (Grounded Theory) by Glaser/Strauss 1998 [56] (pp. 111–119). After reading all the strategies, a final list of 114 codes could be made. It contains a wide variety of terms that show spatial interrelations (e.g., brownfields, energy supply, demand, connectivity, development, transport costs etc.) since spatial planning is a cross-sectoral subject [8] (p. 10). The complete code book is provided in Appendix A Table A2.

Each code comprises all possible varieties of a search term, for example: "food demand", "need for food" and "demand for food" or "energy production" and "production of energy", and always the singular and plural forms. The codes are mainly compound terms, as shown above. However, the individual root words have also been used in order not to exclude any relevant text passages. Thematically related terms were subsumed in 18 different clusters in order to be able to identify the main points of focus in the strategies (see Appendix A Table A3).

The content of each document, including footnotes, was coded using the Acrobat Reader search function. An automated coding, for example with ATLAS.ti, was deliberately omitted in order to become familiar with the contents of the documents during coding. In addition, information losses could be minimized, and correlations could be better recognized, in order to avoid the risk of misinterpretations. During the coding process, all relevant terms were marked, counted and added to the coding table. Forewords, Names (Ministries, Funds etc.) and most footnotes containing the search terms were excluded.

After the completion of the first reading, a second reading had to be carried out with the complete list of 114 codes found in the texts and summarized in the master table so that the codes added later were used equally in all documents. All newly added codes during the second reading were highlighted in a different color to more easily identify where sections in strategies were newly marked and where additions were made.

In the following step, a MS Word document was created for each strategy in which the text parts with spatial interrelations marked by codes were copied. The contained codes were again color-marked and quantified, and the results were added to the master table. The result of this process, beside the qualitative content analysis, was a consistent master table showing the quantitative distribution of all codes in the bioeconomy strategies analyzed. This table shows, on the one hand, how often the terms occur in each strategy, and on the other hand, the spatial interrelations, as shown in Table 1. It presents codes extracted from various documents in their thematic context.

**Table 1.** Examples for codes in text passages of strategies.

| Codes | Text | Strategy |
|---|---|---|
| Development<br>Rural<br>Coastal<br>Supply<br>Demand<br>Regional<br>Supply Chain<br>Biorefinery | "The bioeconomy can significantly contribute to the future development of rural and coastal areas because it will promote both supply and demand actions with regional dimension, such as the creation of supply chains for residues and waste as feedstock for bio-based industries, setting up of a network of small-scale local biorefineries or developing aquaculture infrastructures." | EC/2012 [31] (p. 27) |
| Land take<br>Redevelopment<br>Brownfield<br>Rural Area | "One way to reduce the rate of land take is through the redevelopment of brownfields to make better use of neglected land. Brownfield sites are derelict and underused or even abandoned former industrial or commercial sites, which may have real or perceived contamination problems. Redevelopment of these sites has many environmental advantages: relieving pressure on rural areas . . . " | EC/2018 [32] (p. 78) |
| Available land<br>Brownfield | "In order to have sufficient land available for sustainable production in the future, the use of soil for other purposes must be reduced. The decline in areas suitable for agriculture is to be counteracted by zoning and increased brownfield management." | AT/2019 [37] (p. 29) |
| Regional<br>Energy<br>Bio-based products | "Regional and decentralised initiatives offer the opportunity to organise regional materials cycles and energy cycles for biobased products directly at the appropriate location." | DE NPS/2014 [26] (p. 21) |
| Competition for land use | Furthermore, studies should also be carried out into whether and how food production will change though increasing competition for land use in Germany, and into the impact this may have on the EU internal market and the world market. | DE RS/2010 [33] (p. 37) |
| Development<br>Rural<br>Urban | "The bioeconomy will thus bring with it new economic activities to drive development in the rural setting, and an interaction between rural and urban areas." | ES/2016 [39] (p. 27) |
| Land use planning<br>Urban planning | "Promotion of bioeconomy growth must also have a role in land use and urban planning." | FI/2014 [40] (p. 26) |

## 3. Results

During the process of analyzing, not only the frequency of the spatially relevant terms was evaluated, but also the context in which they were embedded, and whether these terms gave rise to topics. The importance attached to the sustainable implementation of the bioeconomy can be derived from the allocation to certain chapters. Based on the tables of contents, twelve different "chapters" were defined that summarize comparable contents, ranging from "Summary/Abstract" over "Strategic Objectives" and "Measures/Actions/Initiatives" to "Conclusions" and "Case Studies/Examples". The assessment of the master table reveals that three chapters dominate (Appendix A Table A4): "Measures/Actions/Initiatives" (193 codes), "Background/Status" (159 codes) and "Guidelines/Policy Framework" (97 codes). On the other hand, in the chapter "Summery/Abstract", which is usually read most frequently, spatial relevant terms were found only in four of the twenty strategies. In the following sections, the spatial references in the individual strategies and policy papers are described and allocated to the chapters with the highest number of codes in the document. The essential spatial aspects from other chapters are also highlighted. The description starts with the chapter with the highest number of codes. The others follow in descending order. In the last section, strategies are

summarized with a few codes or without clear reference to a specific chapter. Each of the codes described contains a reference to the relevant spatial planning strategies as outlined in Section 1 (e.g., ST1).

### *3.1. Codes Relating to "Measures, Actions, Initiatives"*

The chapter "Measures/Actions/Initiatives" contains a total of 193 spatially relevant codes distributed among 13 different strategies.

The largest number of terms with spatial relations can be found in the European Commission's Bioeconomy Strategy of 2018 "A Sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment" [32]. Seventy relevant terms appear in the integrated action plan. This is also a significant increase compared to the EC Strategy of 2012, where only 11 codes can be found in this thematic field. This change in the orientation of the content of these two documents can also be seen in the dominant spatial notions found. Whereas in the strategy released in 2012, the term "biorefinery" appears most frequently (6x), followed by "development" (5x), "local" (5x) and "regional" (5x), in 2018, "urban" (14x) comes first. Behind this, "local" (7x), "rural area" (7x) and "brownfield" (6x) follow at a clear distance. The term "development" appears only in fifth place (5x). The change towards a sustainable orientation can be clearly read from the most frequently used expressions. The 2012 strategy (described in detail under Section 3.3) is dominated by the topics of transport, renewable resources and demand (Appendix A Table A3). In 2018, the emphasis lies on other aspects. For example, the importance of the decentralized organization of the bioeconomy (ST4) is stressed. The first processing of biogenic raw materials should take place as close as possible to the production site (ST4) (see also Appendix A Table A3). This can be in rural, urban or peri-urban areas. Decentralization is also seen as an opportunity for economic development at the local level (ST4) (p.30). The urban space is increasingly becoming the focus of possible measures. On the one hand, it is gaining in importance as a production location (urban farming). On the other hand, there are more and more brownfields (built-up areas with no or only partial use [57]) that can be converted into new utilizations, thus relieving the pressure from the conversion of agricultural land into building land (ST1) (pp. 76–78 and Table 1). The redevelopment of brownfields can also be seen as a kind of "circular economy on land-use" (p. 78).

The terms "brownfield" and "development" point to an important result of the analysis. The number of mentions in a strategy does not automatically correlate with spatial relevance. While the word "brownfield" is 100% spatially relevant when appearing across all the strategies examined (see Table 2), for the term "development", this is only the case in five percent of the citations. Specifically, this term was used 108 times in EC/2012 and 107 times in EC/2018. The ratio is similar in the other strategies analyzed. A spatial context arises, for example, in relation to rural development (p. 46) [32] or the redevelopment of brownfields (p. 78 [32] and Table 1).

Table 2 reveals that many other terms always, or at least to a high percentage, have a spatial reference. The most frequent clusters are Planning (5x), Land use + Change (4x), Land Quality + Landscape (3x), Competition (2x). Demand, Development, Energy, Rural, Security, Spatial aspects and Transport only appear once, and codes referring to Availability, Local, Region/regional, Renewable resources, Strategic aspects + Objectives, Supply and Urban always have percentages below 75. In the case of planning topics, the spatial reference is evident. However, the term "land" dominates in all its facets across all clusters. It is about availability, (re-)use, degradation and land use change. Many of these factors can, in turn, be regulated by spatial planning.

**Table 2.** Codes with a spatial relevance between 100% and 75% and the related cluster.

| Code | Percentage | Cluster |
|---|---|---|
| Brownfield | 100 | Land use + Change |
| Competition for arable land | 100 | Competition |
| Consumption of land | 100 | Land use + Change |
| Demand for renewable resources | 100 | Demand |
| Food and water security | 100 | Security |
| Land abandonment | 100 | Land Quality + Landscape |
| Redevelopment | 100 | Development |
| Soil sealing | 100 | Land use + Change |
| Spatial development | 100 | Spatial aspects |
| Spatial development planning | 100 | Planning |
| Spatial energy planning | 100 | Planning |
| Transport distance | 100 | Transport |
| Urban planning | 100 | Planning |
| Valuable land | 100 | Land Quality + Landscape |
| Land take | 83 | Land Quality + Landscape |
| Land Use Change | 82 | Land use + Change |
| Spatial planning | 80 | Planning |
| Transportation cost | 80 | Transport |
| Rural and coastal area | 80 | Rural |
| Competition for bioresources | 75 | Competition |
| District heating | 75 | Energy |
| Land use planning | 75 | Planning |

The Latvian bioeconomy strategy [44] has the second most spatial references in the chapter "Measures, Actions, Initiatives", with 26 mentions. As one of the few documents analyzed, it refers directly to the need for spatial planning frameworks for the development of the bioeconomy, in this specific case for the development of rural areas (ST4). The conservation of agricultural land (ST2) as a means to create a competitive advantage is at the center of the discussion. The correlation between the loss of production land in agriculture and forestry and population decline is pointed out. In order to counteract this, optimal land use is required, which should be achieved through spatial planning (ST1+2) (p. 26). A medium-term land policy is requested that transforms unused areas into productive land. This is to be achieved by using local resources on a scientifically sound basis (p. 29). The importance of land use is also reflected in the fact that it is the most commonly used spatial term (14x) in the strategy, followed by "Development" (9x), "Local" (4x) and "Rural Territory" (4x). The strategy thus refers, on the one hand, to the necessary legal framework conditions for a sustainable soil policy at national and regional levels, and, on the other hand, to possibilities for controlling land use with spatial planning instruments at the local level (ST1,2+5). In addition, it is the only strategy analyzed that also identifies risk factors (Appendix A Table A4) for the development of the national bioeconomy (p. 21+22).

The analysis of the Swedish strategy [46] revealed a total of 22 codes in the chapter "Measures, Actions, Initiatives". The focus is on socio-economic consequences (e.g., the influence of new value chains on transport, urban and rural development) and possible conflicts of objectives. These conflicts can arise from different demands on land use, for example, between intensive production of natural

raw materials and environmental protection (ST3). Research at the local, regional and global levels will be required to solve these conflicts (p. 29). In the chapter "Background", it is pointed out that, due to the broad orientation of bioeconomy, research must also take place in many subject areas. In addition to technical subjects, spatial planning is also mentioned. However, there is no further consideration of the subareas in which specific research should be conducted (p. 14+15).

### *3.2. Codes Relating to "Background/Status"*

The chapter "Background/Status" with a total of 159 spatially relevant terms can be found in twelve different strategies. Most (29) have been identified in the Austrian [37], followed by the Finnish [40] with 27, and the German Policy Strategy [26] with 25 relevant terms. The latter will be discussed later in Section 3.4. In addition, the British and Irish strategies have their largest number of codes in this chapter (9 and 6 terms respectively).

The Austrian strategy, "Bioeconomy—A Strategy for Austria" [37], mentions energy most frequently (6x) among the spatially relevant terms. The emphasis there is on energy recovery (p. 25 + 27). Attention is also drawn to the possibilities of energy production by using wastewater treatment plants (p. 44). The requirement for spatial energy planning is pointed out (ST1) in order to ensure the integration of these services, for example, into district heating systems (ST4). The second most common term is "land availability" (5x), followed by "brownfield" and "soil sealing" (4x each). This illustrates the great importance attached to the preservation of agricultural land (ST2) if sustainable production of biogenic raw materials is to be guaranteed (p. 39 and Table 2). Kalt et al. [58] have calculated three scenarios for Austria in which transformation to a low-carbon bioeconomy could be successful. They concluded that this is possible until 2050 without raw material imports, if "energy consumption is reduced significantly, other renewable energy sources are employed intensively, and biomass and bioenergy are utilized in an efficient way" (p. 15). This result can be generalized for Austria and the EU to the extent that the efficient and careful use of existing resources (arable land, forest, water ...) must be a general objective if the transition is to be sustainable and successful. This is underpinned by the significant reduction of annual soil sealing (ST1+2) as one of the main objectives of the Austrian bioeconomy strategy (pp. 16, 29, 39).

The Finnish strategy, "Sustainable growth from bioeconomy—The Finnish Bioeconomy Strategy" [40], emphasizes the importance of decentralized and resource-efficient solutions (ST2+4) in the bioeconomy in this chapter. One of the priorities is energy self-sufficiency, which may be achieved by using the natural resources available in the respective production areas (p. 18) (ST1+4). The importance of the energy sector for the Finnish bioeconomy is also reflected by the fact that this term is used most frequently (7x), as it is in the Austrian publication. At the same time, a decentralized bioeconomy would also open new development opportunities for rural areas (ST4). This is also the case in connection with the development of urban regions, where sustainable solutions for energy and water supply can be found with the support of the bioeconomy (p. 24) (ST1). In this context, urban planning must also be included in the development of the bioeconomy (p. 26 and Table 1)

The analysis of the British strategy, "Growing the Bioeconomy—improving lives and strengthening our economy: A national Bioeconomy strategy to 2030" [41], revealed only a few spatially relevant codes (a total of 11), which are concentrated mainly in the chapter "Background/Status" (9). They essentially refer to the local and regional importance of the bioeconomy in relation to the availability of raw materials and its positive impact on rural and urban communities through its decentralized nature (pp. 33, 35, 37, 45) (ST4). Moreover, the author (Ministry for Business and Industry) and the contents of the document show that this is an industrial strategy that emphasizes the technological and economic implementation of the bioeconomy.

The Irish strategy, "National Policy Statement on the Bioeconomy" [42], includes terms with spatial relations (15 in total) in several chapters (see Appendix A Table A4). The focus is on regional and rural development (ST4). It is emphasized, for example, that a bioeconomy can help to slow down the decline of rural areas, as many related businesses are anchored at the local level (ST4). In this

context, reference is made to the article by Devaney and Henchion [59], for which they interviewed 75 experts in Ireland on the possible impact of the bioeconomy. They conclude that a successful transition will lead to, among other issues, a massive change in land use and land structures. An economically, environmentally and socially sustainable implementation can only succeed under certain conditions. In this context, the authors cite the example of the application of the cascading principle, clear environmental thresholds and the development of robust feasibility assessments (p. 1410). This points to the importance of a holistic approach if a bioeconomy is to be successfully implemented, as outlined in Section 1.

### *3.3. Codes Relating to "Guidelines/Policy Framework"*

The chapter "Guidelines/Policy Framework" contains 97 terms with spatial interrelations in six different strategies. Most of them (54) could be found in the European Commission's Bioeconomy strategy of 2012, "Innovating for Sustainable Growth—A Bioeconomy for Europe" [31]. This result is obvious, since a transnational strategy of the European Union should provide a political framework for its members. As stated above, transport, renewable resources and demand are dominating issues in this strategy. Additionally, the regional dimension has already been highlighted. The development of new distribution chains and networks of local biorefineries could contribute to strengthening regional economies (ST4). However, a large number of influencing factors must be taken into account. These include, for example, transport and storage costs and aspects of land use (p. 27) (ST4). In the context of the latter, the strategy points out that there was still no legally binding protection for soil legislation at the EU level (p. 29). Since then, the "Thematic Strategy for Soil Protection" of 2006 [60], has been integrated into the Environmental Impact Assessment (EIA) Directive in 2014 [61]. The Commission also considered this to be the cause of the slow pace of reuse of brownfields (ST1), and also points to the need for research in the context of a broad range of ecosystem services of landscapes and their relationships to agricultural production (ST3). The strategy also highlights the importance of green infrastructure or habitat connectivity for pest control and carbon storage (p. 29+30). In this context, the Commission identified a need for further research. The research results can, in turn, be implemented with spatial planning instruments (ST4). The term "spatial planning" is only used once in the strategy (p. 33). Its importance is mentioned in connection with the increasingly intensive and varied use of coastal areas. There, for example, the demands of a constantly growing population and the increased use of offshore areas are meeting. Spatial planning measures at the regional and local levels can prevent conflicts and ensure sustainable development (ST1+5).

Another strategy with numerous codes in this chapter is the Austrian one (17 codes). The topics addressed in this chapter (energy, land availability, brownfields) have already been discussed in detail in Section 3.2. It is worth mentioning that in this chapter, the "Sustainable Development Goals" are mentioned first as the framework for the bioeconomy. The guidelines of the Austrian strategy have been adapted to these SDGs (p. 25).

In 2018, The Netherlands published a position paper on the development of the bioeconomy at the national level [45]. The policy framework rests on eight pillars. One deals with regional strategy and rural development (ST4). It emphasizes the role of regions in the development of the bioeconomy. Furthermore, it also stresses opportunities for the revitalization of rural areas (ST4). It is also stated that at the regional level, the available biomass must be optimally used and managed in the same way as agricultural land (p. 4) (ST2). Another pillar refers to new economic opportunities which would not negatively affect the availability of food and water (ST3,4+5), land rights and human rights (p. 4).

The Dutch strategy is an example of the fact that, despite its brevity (8 pages), it contains many spatially relevant aspects. It also refers to policy papers already drafted by the European Commission, for example, that of the Standing Committee on Agricultural Research (SCAR [62,63]). This committee has set up a working group [64] that discusses the further development of the bioeconomy at the EU level, and has drawn up a "Strategic Knowledge and Innovation Agenda" [65]. Among others, it points to the increasing importance of urban-rural relations and urban agriculture (pp. 6+7). Patermann and

Aguilar [66] underline the importance of SCAR as a forum for discussion among the services of the EU Commission, relevant research communities and stakeholders, also in the context of bioeconomy [67]. The Netherlands refer to this working group and the importance of linking a bioeconomy with other sectors, for example, urban planning. This should make the bioeconomy more sustainable, more nature-oriented and more competitive (p. 6).

### *3.4. Codes Relating to "Strategic Objectives"*

An analysis of the codes for the German National Policy Strategy on Bioeconomy yielded a number of 31 spatial terms. Two thematic areas are dominant. On the one hand, it is a matter of reducing the use of arable land by building development and transport infrastructure (p. 66) (ST1). On the other hand, with regard to the use of biogenic raw materials, the strategy focuses on securing the supply of food, which must have priority over all other possible uses (ST5) (p. 67). The importance of these themes is also reflected by the fact that these codes (i.e., Food supply, Food security, Renewable raw material) are among the most frequently used in the strategy. The German strategy is the only one of all the strategies analyzed to place the bioeconomy in an international context in a more in-depth manner. It is pointed out that an increase in agricultural productivity is still necessary in developing countries. Improved land use planning and optimized value chains could reduce the competitive pressure between food production and other uses. At the same time, this could strengthen rural economies (p. 70). The importance of internationally valid sustainability standards is pointed out in order to ensure environmentally and socially compatible production of renewable raw materials in developing countries. The consequences of direct and indirect land-use changes are particularly highlighted. Among other things, the secured right to land ownership and access to other means of production are regarded as prerequisites for survival in rural areas in developing countries (p. 73).

The document with the second highest proportion of codes (11) in this chapter is the German "National Research Strategy - BioEconomy 2030" [33], which deals with the need for research in numerous fields of bioeconomy. The topics which address spatial interrelations include "Ensuring sustainable agricultural production" issues of sustainable land management, for example, the correlation between land use, ecosystem services and climate change (ST3). According to the authors, this requires not only interdisciplinary research, but also the involvement of decision-makers and stakeholders. To strengthen institutions in rural areas, planning research should be carried out alongside other disciplines (p. 23). Moreover, the strategy deals primarily with economic and technological aspects of the bioeconomy.

### *3.5. Codes Relating to "Introduction/Definitions"*

The Italian strategy, "BIT—Bioeconomy in Italy" [43], is the only one among those analyzed that has a larger share of spatially relevant codes in the chapter "Introduction/Definitions" (11 out of a total of 31). In this context, the importance of the regional level is emphasized by presenting a special form of decentralized organization of the bioeconomy system, i.e., the "Distributed Business Model" (p. 22). In this model, modules or production sites form a network of nodes that are connected to each other as needed, for example agro-energy plants (p. 23) (ST4). Imbert et al. confirm this market-oriented approach in their comparison of Italian and German policy strategies [68]. The Italian strategy was developed in a bottom-up process involving relevant stakeholders, while the German strategy was elaborated by the government emphasizing research and innovation (p. 9). Similarly, both strategies focus on the securing and optimal use of arable land (ST2). In addition, both policies point to the importance of the bioeconomy for the positive economic development of rural regions (ST4).

Other dominating topics of the Italian strategy are the availability of biogenic raw materials (p. 21) (ST2), energy production (p. 23) (ST4), regional and rural development (p. 57) (ST4) and integrated land use planning (ST5) (p. 51). It is mentioned that the latter must also include underused, abandoned and contaminated land. The availability of these areas is important for the production of biomass for the bio-based industry (pp. 51+53) (ST2). The large demand for biogenic raw materials

including byproducts and waste streams is also mentioned in connection with a contribution to the Euro-Mediterranean bioeconomy (p. 54). Another challenge mentioned is the pressure on marine landscapes caused by tourism, leisure activities and urbanization (ST1+2), and, in connection with this, the preservation and sustainable valorization of its beauty (p. 52) (ST3). In the Italian strategy, "Landscape" is also the most frequently used spatially relevant term (5x) followed by "Local" (4x) and "Energy" (3x).

This strategy also refers to the Sustainable Development Goals of the United Nations (p. 42) and identifies seven different goals directly related to the bioeconomy (the SDG's 2, 7, 8, 9, 12, 14 and 15).

### *3.6. Codes Relating to "Case studies/Examples"*

In the French national strategy, "A Bioeconomy Strategy for France" [34], spatially relevant terms can be found solely under "Case studies/Examples". These refer to the energy sector. For example, a plant is presented that produces superfluous nitrogen for the use outside the local area, but also combined heat and power for the local electricity and heat supply (ST1+4). Discharged water is used for the irrigation of energy wood areas (p. 7). This practical example refers to the many advantages of processing biogenic raw materials at the production site.

Another special aspect of the French strategy is the fact that it contains no spatially relevant codes in the chapter "Measures/Actions/Initiatives". This is explained by the fact that these topics are part of the separate action plan, "A Bioeconomy Strategy for France 2018-2020 action plan" [35]. It is remarkable that the French action plan does not comprise any spatial statements, which can also be clearly seen in Appendix A Table A3. Looking at the five core themes addressed (p. 2), the lack of spatial reference becomes more comprehensible. The aim of this strategy is to increase knowledge about bioeconomy and to raise public awareness thereof. The prerequisites for matching supply and demand are to be created. Bioresources should be produced and processed in a sustainable manner and, finally, any obstacles that arise are to be removed and sufficient financial resources be made available. No spatial aspects could be derived from these topics based on the set of codes.

### *3.7. Codes in Other Strategies*

The following strategies have either few codes or no focus on a particular chapter, and are listed according to the total number of codes found. In the case of the "Spanish Bioeconomy Strategy 2030 Horizon" [39], codes with spatial references (a total of 15) were found mainly in the chapters "Introduction/Definitions" (7) and "Background/Status" (6). For example, the lack of availability of water as a limiting factor is pointed out (p. 24). In order to manage these challenges sustainably, the use of science and technology is required. This, in turn, can create new jobs with special skills that need to be fostered. In the strategy, it is an essential objective that the raw materials be processed at the place of their production with the help of biorefineries (ST4). This enables the development of rural areas to be promoted and interaction with urban areas to be proceeded (p. 27 and Table 1). Overall, this strategy aims at a knowledge-based development of the bioeconomy, with an economic and technological orientation. This is also confirmed by Lainez et al. [69] in their analysis of the Spanish bioeconomy strategy. Both the long-term strategic goals and the corresponding measures point in this direction (pp. 6+7). The only codes that occur more than once in the analysis (3x Development, 2x Biorefinery and 2x Demand) also show this focus.

The English version of the Norwegian strategy, "Familiar resources—undreamt of possibilities" [48], consists only of a detailed summary without page numbers or further chapters with eight spatial relevant codes. The most direct spatial reference can be seen in the indication that spatial planning must take place across existing administrative boundaries in order to further develop the aquaculture industry. This concerns both the local and the regional levels. In the forest and timber industry, there is a need to optimize the transportation of timber. This is to be achieved with the help of a national transport plan. In its strategy, the Norwegian government also stresses the importance of

the sustainable production of biogenic raw materials (ST2+3). Supplying the population with food must have the highest priority when using these resources (ST5).

The policy paper of the OECD, "The Bioeconomy to 2030—Designing a Policy Agenda" [13], contains only four different codes (2x Biorefinery, 2x Development, 1x Regional and 1x Transportation cost). These are assigned to the chapters "Challenges", "Scenarios/Prospects and "Conclusions". For example, the great importance of biotechnology in many important areas of the bioeconomy (e.g., food production, renewable energy and preservation of biodiversity) is highlighted. However, their potential can only be exploited if regional, national and global policies support this development (p. 8). At the regional level in particular, this should also include optimized legislative framework conditions for sustainable spatial development. This policy paper also points out that biorefineries should be as close as possible to biogenic raw material sources because of the high transport costs (p. 13) (ST4). This is seen as a logistical problem and not as an opportunity to support the sustainable development of rural areas.

The OECD policy paper focuses on the further development of biotechnology and its applications in agriculture, health and industry. Another important issue, however, is the adequate supply of biogenic raw materials. Overall, economic aspects are dominating. Staffas et al. [11] confirm this in their analysis of national and transnational bioeconomy strategies.

Based on the three codes found (Energy Production, Biomass Supply, Use of Land), "Canada's Bioeconomy Strategy" [47] has only a small spatial reference in its content. In the areas of food and energy production, external factors such as climate change and scarcity of resources require ever faster innovations (p. 6). In order to make optimum use of the opportunities offered by bioeconomy, industry must be provided with biomass. This, in turn, requires optimal management of agricultural and forestry lands (p. 7) (ST2). A special feature of the Canadian strategy is the consideration of the indigenous population. Based on their traditional knowledge and land use, possibilities are to be created to let them participate in the positive effects of the bioeconomy (p. 42). The involvement of indigenous people should take the form of a partnership.

The Canadian bioeconomy strategy shows a strong technological-industrial orientation. All the proposed recommendations in the fields of regulations, biomass supply and value chains point in this direction. Even the term "ecosystem" is used exclusively in connection with economic optimization and not in the biological sense (pp. 40–42). The importance of research and development for the successful implementation of bioeconomy is also repeatedly emphasized. The Department of Agriculture and Agri-Food, referred to as Agriculture and Agri-Food Canada (AAFC), also deepens this in an article written prior to the publication of the strategy [70].

An analysis of the "Denmark Plan for Growth for Water, Bio & Environmental solutions" [38] revealed that there are only three spatial relevant terms mentioned: "Development", "Transporting" and "Energy". Looking at the text passages concerned, it is evident that the terms are not related to sustainability. Rather, they are about cost reduction in the production of biomass. On the other hand, regulations relating to nature, environment and energy are to be revised in order to reduce barriers to business opportunities (p. 4).

In the "National Bioeconomy Blueprint" of the USA [49], only the terms "Arable Land", "Regional" and "Bioenergy" refer to a spatial relevance. The first part of the document, "Background and Impacts of the US Bioeconomy", deals, for example, with the limited availability of arable land (p. 10) for supplying the world's population with food. Genetic engineering, DNA sequencing and high-throughput technologies are named as the result of long-term biological research, and should, at the same time, be the foundation for further developments and discoveries in order to cope with the societal challenges of the future (p. 15). The second part deals with the strategic goals of the bioeconomy and how they should be achieved. For example, strengthened research and development should increase the availability of bio-based products and fuels by building regional bioenergy systems (p. 19). This strategy and that of Canada have very few spatial references, despite their lengths, i.e., 48 and 35 pages respectively.

## 4. Discussion

In the following section, the results are linked back to the five spatial strategies that should be considered in the bioeconomy transition, as well as to the Sustainable Development Goals.

Concerning the development of compact settlement areas, different references can be found in the policy papers. On the one hand, the aim is to reduce the pressure on arable land by controlling land use and avoiding conflicts (Latvia). On the other hand, it is about energy production and supply. The Austrian strategy, for example, considers energy generation from wastewater and emphasizes the importance of integrated spatial and energy planning when it comes to the concrete application. This creates the prerequisites for the successful implementation of local energy networks, for example, by ensuring a sufficiently high settlement density. At the level of local spatial planning, several instruments are available for the zoning of agricultural or environmental priority areas. The medium-term framework is defined by development concepts. An essential element in this planning instrument for implementing the first strategy is the definition of settlement boundaries. These prevent the spread of development into agriculturally valuable areas. The contents of development concepts are specified in zoning plans. The building scheme is then used for the small-scale structuring on the level of the individual parcel [71].

Another important issue to avoid the loss of arable land is the reuse of brownfields for settlements and business locations. In its 2012 strategy, the European Commission identified the importance of the reuse of brownfields for the preservation of agricultural land. In this context, the Commission cites the lack of legal soil protection as one of the reasons for the slow implementation. As this deficiency was remedied in 2014, there are other reasons to be mentioned. These include, among others, the higher cost of making the land usable (demolition, conversion, etc.) and, in some cases, the risk of contamination of the site. So, measures must be found to simplify the reuse of brownfields and to create reliable framework conditions.

Looking at the establishment of agricultural priority areas, an important issue is the conservation and optimized use of agricultural land as a prerequisite for sufficient production of raw materials for the various applications in the bioeconomy. The topics are the risks caused by the reutilization of soils for settlement areas and transport infrastructure (Germany) and the abandonment of land due to population loss (Latvia). In order to counteract these dangers and secure the arable land, several strategies point to the various applicabilities of spatial planning. Latvia refers to this in connection with optimal and controlled land use at the local level. The Austrian strategy also emphasizes their importance when it comes to the conservation of arable land and the avoidance of soil sealing. Some of Austria's federal states already have instruments on the regional and local levels to preserve agricultural land (e.g., Upper Austria, Lower Austria and Styria).

The protection from use by technical and leisure infrastructure is hardly addressed in the policy papers analyzed. One example is the prevention of the reutilization of arable land for transport infrastructure (Germany). Italy addresses the negative impact of leisure, tourism and urbanization specifically on the coastlines. However, this is also true for other attractive landscapes, for example in the Alpine region. Spatial planning can control this at regional and local levels and, for example, define areas for tourism and leisure, but also protected zones. The definition of boundaries for settlement development is also a valuable tool at the regional level.

The negative impacts of intensive agriculture on the environment in general, and on ecosystem services in particular, are discussed several times, and lead us to the consideration of negative environmental impacts by the zoning of ecological priority areas. Spatial planning can compensate for these effects through various measures. At the regional level, this can be the definition of green corridors. At the local level, for example, ecological priority zones can be designated. These issues are barely addressed in bioeconomy strategies.

Another set of issues addressed in the Gothenburg Protocol deals with transport. The first objective is to decouple traffic from economic growth in order to reduce congestion and other negative effects of transport. A further objective is the demand for a balanced regional development. This is to

be achieved by reducing economic imbalances and preserving viable rural and urban communities (p.12). In this context, reference is made to demands in the European Spatial Development Perspective (ESDP) [21]. For example, the ESDP mentions improved accessibility as a prerequisite for polycentric spatial development, and also emphasizes the principle of sustainability (p.35-36). According to ESDP, polycentric development creates the basis for balanced regional development and avoids concentrating on a few core areas of the EU (p. 20). This approach of dispersed nodes also corresponds to the model of decentralized concentration [21,72]. The Protocol mentions the establishment of the "European Spatial Planning Observatory Network" (ESPON) [73] as one of the measures to achieve the objectives. With this network, territorial indicators are to be created in order to be able to analyze the regional influence of community policies.

Further objectives are the diversification of income opportunities in rural areas and the establishment of integrated development strategies for urban and ecologically sensitive areas. The latter objectives and measures yield important results. The regional level is considered essential for the successful and sustainable implementation of the bioeconomy in many of the policy papers. Numerous strategies therefore point to the necessity of using spatial planning if the implementation of the bioeconomy is to be successful and sustainable at regional and local levels. In all cases, however, the step towards the description of the required instruments and their possible applications is missing. Dietz et al. [74] also come to this conclusion in their comparison of national strategies, which also contains ten of the policy papers analyzed here. Looking at regional governance, they see a strong discrepancy between the promotion and regulation of the bioeconomy.

Spatial planning already offers various instruments and planning processes for managing regional development. These can relate to specific subject areas such as the systematic use of wind power or deal in an integrative way with all spatially related topics of a region [4]. However, most of these instruments are in need of adaptation or reorientation in order to support the sustainable implementation of the bioeconomy. These spatial requirements include the preservation of agricultural land, the selection and securing of sites for biorefineries, the spatial organization of supply chains and transport routes, and the optimized use of bioenergy products, e.g., in district heating systems. Stöglehner, therefore, argues for the establishment of small towns as nodes for the distribution of resources and energy sources. This type of settlement can then provide impulses for the development of rural regions [2].

Another complex of spatial issues relates to urban regions and urban-rural relations and their relevance for the implementation of the bioeconomy. These topics are barely addressed in the bioeconomy strategies, but they have recently gained importance for sustainable spatial development, because of increasing importance of urban food production and the constant loss of arable land. The ESDP [21] addresses the relevance of the urban-rural partnership by assigning the role as motors for regional development, especially to rural towns (p. 25).

In the context of urban-rural relations and issues affecting urban regions, besides the EU, some countries (Austria, Finland and The Netherlands) refer in their strategies to the requirements of spatial planning in general and urban planning in particular. The same applies here as described above. The necessary planning instruments are often already available, but must be consistently applied or adapted. This also results in the need for future research. The European Commission [31] also identifies this requirement and expects the findings to be implemented in spatial planning instruments. The demand for research exists, on the one hand, in the field of urban planning, and on the other hand, in the context of regional planning. The latter, for example, involves the provision of effective instruments for securing agricultural land, also at the local spatial planning level. In addition, it will be necessary to clarify how small towns in rural areas can be turned into hubs of the material flows of the bioeconomy, and which instruments of spatial planning can be used to support this. Apart from specific instruments, most regions still lack strategic planning and governance regarding how the bioeconomy could be best deployed [75]. Urban planning is about preserving the existing traditional agriculture while establishing new forms of production (e.g., vertical farming). Overall, bioeconomy strategies so far have ignored the process dimension that can be covered within spatial planning processes.

When analyzing potential intersections between the spatially relevant topics of bioeconomy strategies and SDGs, it can be seen that direct references are seldom made, but that there are overlaps (see Table 3).

**Table 3.** The ten most relevant Code Clusters and their relationships to SDGs.

| SDG | Energy | Development | Land Use | Regional | Local | Supply | Rural | Transport | Urban | Land Quality |
|---|---|---|---|---|---|---|---|---|---|---|
| Goal 1 | | | | X | | | | | | |
| Goal 2 | | | | X | | | X | | | X |
| Goal 3 | | | | | | | | | | |
| Goal 4 | | | | | | X | | | | |
| Goal 5 | | | | | | | | | | |
| Goal 6 | | | | | X | X | | | | |
| Goal 7 | X | | | | | X | | | | |
| Goal 8 | | | | | X | | | | | |
| Goal 9 | | | | X | | | | | | |
| Goal 10 | | | | | | | | | | |
| Goal 11 | | X | | X | X | | X | X | X | |
| Goal 12 | | X | X | | X | X | | | | |
| Goal 13 | | | | | X | | | | | |
| Goal 14 | | | | | | | | | | |
| Goal 15 | | X | X | | X | X | | | | X |
| Goal 16 | | | | | | | | | | |
| Goal 17 | | | | X | | | | | | |

Table 3 shows that the ten most important clusters can be found in one or more of the SDGs. This is most often the case with the terms "local" and "supply". Although the term "sustainability" appears in almost all goals, it only has a spatial reference in three of them. "Energy" can only be found in the "SDG 7" (Access to Energy for all), while the code cluster "Energy" is the most important in the strategies. Therefore, thematic links between the bioeconomy strategies and SDGs exist, but should be further elaborated in the sense of sustainable development, as only two of the twenty strategies (Austria and Italy) refer directly to the 17 SDGs of the United Nations. These links can be improved by spatial planning, as all SDGs contain spatial components.

## 5. Conclusions

In a nutshell, it can be concluded that spatial references are present, to very different extents, in the analyzed bioeconomy strategies and policy papers (see Table A4). While they are numerous in some (EC/2012, EC/2018, DE NPS, AT), they are (almost) completely absent in others (FR ST, FR AP, OECD, CA, NO, USA). At the same time, clear differences in sustainability orientation and interpretation in general and with regard to spatial development in particular can be identified. In this context, the influence of the EU overarching policy frameworks on sustainability orientation is also clearly evident for those countries mentioned first. In contrast, the policy papers of the OECD, Canada, Norway and USA are dominated by the desire for economic prosperity and technological progress. Issues such as the scarcity of resources and the preservation of agricultural land are addressed but are not the focus, and no solutions or measures are outlined. They reveal a one-sided economical orientation and negligence of the ecological and social dimension and the services that the bioeconomy could provide to society. This also applies to certain EU countries whose strategies also do not focus on the sustainable implementation of a bioeconomy, e.g., France, Denmark and the United Kingdom. Thus, diverging goals and discussion lines can also be derived from the differently emphasized main strategies of spatial planning. However, spatial planning has the potential to create the conditions for a

sustainable implementation of the bioeconomy on the regional as well as local levels. The strategies and policy papers deal with the pillars of sustainability in varying depths. A stronger link to SDGs must therefore be considered in order to ensure sustainable development. Many of the targeted objectives can effectively be achieved with spatial planning instruments, and discussed in spatial planning processes involving the decision-makers, relevant stakeholders and the general public.

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## Appendix A

**Table A1.** Content structure of the analyzed strategies and policy papers by chapters.

| Strategy/Year of Publication | (Executive) Summary/ Abstract | Introduction/ Definitions | Vision | Background/ Status | Challenges | Strategic Objectives | Guidelines /Policy Framework | Measures/ Actions/ Initiatives | Risk Factors | Scenarios/ Prospects | Conclusions | Case Studies/ Examples | Sum | Pages | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EC/2012 | | x | | x | x | x | x | x | | x | | | 7 | 64 | [31] |
| EC/2018 | | x | | x | | x | x | x | | | x | | 6 | 107 | [32] |
| AT/2019 | | | x | x | x | x | x | x | | x | | | 7 | 71 | [37] |
| DE NPS/2014 | x | x | x | x | x | x | x | x | | | | | 8 | 80 | [26] |
| DE RS/2010 | x | | x | x | x | x | | x | | x | | | 7 | 56 | [33] |
| DK/2013 | x | | | x | | | | x | | | | | 3 | 12 | [38] |
| ES/2016 | | x | | x | | x | x | x | | | | | 5 | 46 | [39] |
| FI/2014 | x | x | x | x | | x | | x | | | | | 6 | 17 | [40] |
| FR ST/2017 | | x | | x | | x | | | | | | x | 4 | 8 | [34] |
| FR AP/2018 | | | | | | | | x | | | | | 1 | 12 | [35] |
| GB/2018 | x | x | x | x | x | x | x | x | | x | x | x | 11 | 30 | [41] |
| IE/2018 | | x | x | x | | x | x | x | | | x | x | 8 | 20 | [42] |
| IT/2017 | x | x | | x | x | | | x | | | | x | 6 | 76 | [43] |
| LV/2017 | | x | | x | | x | | x | x | | | | 5 | 32 | [44] |
| NL/2018 | | x | | x | | | x | x | | | | | 4 | 8 | [45] |
| SE/2012 | x | x | | x | x | | | x | | | | | 5 | 36 | [46] |
| OECD/2009 | x | | | | x | x | x | | | x | x | | 6 | 18 | [13] |
| CA/2019 | x | x | | | | | | x | | | x | x | 5 | 35 | [47] |
| NO/2016 | x | | | | | | | | | | | | 1 | 8 | [48] |
| USA/2012 | x | | | x | | x | | | | | x | | 4 | 48 | [49] |

x = Chapter appears in this strategy.

**Table A2.** Codes in alphabetical order with cluster affiliation.

| Code | Cluster |
|---|---|
| Arable land | Land Quality + Landscape |
| Availability - available | Availability |
| Availability of biomass - Biomass availability | Availability |
| Availability of food - Food availability | Availability |
| Availability of raw material | Availability |
| Availability of renewable resources | Availability |
| Availability of resources - Resource availability | Availability |
| Bio-based product | Renewable Resources |
| Bioenergy | Energy |
| Bioenergy production | Energy |
| Biomass demand - Demand for Biomass | Demand |
| Biomass supply - Supply of Biomass | Supply |
| Biorefinery | Renewable Resources |
| Bioregion | Region - Regional |
| Brownfield | Land use + Change |
| Competition | Competition |
| Competition for arable land | Competition |
| Competition for bioresource | Competition |
| Consumption of land | Competition |
| Competition for raw material | Competition |
| Connectivity | Transport |
| Consumption of land | Land use + Change |
| Demand | Demand |
| Demand for natural resources | Demand |
| Demand for bioresources | Demand |
| Demand for renewable resources | Demand |
| Development | Development |
| Distance | Transport |
| Distribution | Transport |
| District heating | Energy |
| Energy | Energy |
| Energy demand - Demand for energy | Energy |
| Energy production - Production of energy | Energy |
| Energy sector | Energy |
| Energy security | Energy |
| Energy supply - Supply of energy | Energy |
| Food and nutrition security | Security |
| Food and water security | Security |
| Food demand - Demand for food | Demand |

**Table A2.** *Cont.*

| Code | Cluster |
|---|---|
| Food insecurity | Security |
| Food security - Food safety | Security |
| Food supply - Supply of food | Supply |
| Geospatial | Spatial aspects |
| Indirect Land Use Change (ILUC) | Land use + Change |
| Interregional | Region - Regional |
| Land abandonment | Land Quality + Landscape |
| Land availability - available land | Availability |
| Land change | Land use + Change |
| Land demand | Demand |
| Land management | Land Quality + Landscape |
| Landscape | Land Quality + Landscape |
| Land take | Land Quality + Landscape |
| Land Use - Use of land | Land use + Change |
| Land Use Change - Change in land use | Land use + Change |
| Land use planning - planning of land use | Planning |
| Land use policy | Land use + Change |
| Legislation | Strategic aspects + Objectives |
| Local | Local |
| Local bioeconomy | Local |
| Local development | Development |
| Local level | Local |
| Local reuse | Local |
| Local rural economy | Local |
| Local use | Local |
| Local, regional and global level | Local |
| Locally | Local |
| Multi-regional level | Region - Regional |
| National strategic plan | Strategic aspects + Objectives |
| Objectives | Strategic aspects + Objectives |
| Planning | Planning |
| Redevelopment | Development |
| Region | Region - Regional |
| Regional | Region - Regional |
| Regional bioeconomy strategy | Region - Regional |
| Regional development | Development |
| Regional level | Region - Regional |
| Regional planning | Planning |
| Regional scale | Region - Regional |
| Regional strategy | Region - Regional |

**Table A2.** *Cont.*

| Code | Cluster |
|---|---|
| Renewable Energy | Energy |
| Renewable energy production | Energy |
| Renewable raw material | Renewable Resources |
| Renewable resource | Renewable Resources |
| Rural | Rural |
| Rural and coastal area | Rural |
| Rural area | Rural |
| Rural development | Development |
| Rural territories | Rural |
| Security | Security |
| Soil sealing | Land use + Change |
| Spatial | Spatial aspects |
| Spatial data | Spatial aspects |
| Spatial development | Spatial aspects |
| Spatial development planning | Planning |
| Spatial energy planning | Planning |
| Spatial planning | Planning |
| Spatially | Spatial aspects |
| Strategic | Strategic aspects + Objectives |
| Strategic objectives | Strategic aspects + Objectives |
| Strategic plan | Strategic aspects + Objectives |
| Strategic planning | Strategic aspects + Objectives |
| Supply | Supply |
| Supply chain | Supply |
| Transport - Transporting - Transportation | Transport |
| Transport distance | Transport |
| Transportation cost - Transport cost | Transport |
| urban | Urban |
| urban area | Urban |
| urban development | Development |
| urban farming | Urban |
| urban planning | Planning |
| urban region | Urban |
| valuable land | Land Quality + Landscape |
| value chain | Supply |

**Table A3.** Sum of Codes in Code Clusters per Strategy and Number of Strategies with respective Cluster.

| Cluster / Strategy | EC 2012 | EC 2018 | AT | DE-NPS | DE-RS | DK | ES | FI | FR-ST | FR-AP | GB | IE | IT | LV | NL | SE | OECD | CA | NO | USA | Sum | Number of Strategies |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy | 6 | 4 | 15 | 14 | 2 | 1 | 0 | 14 | 3 | 0 | 1 | 2 | 5 | 1 | 0 | 2 | 0 | 1 | 0 | 1 | **72** | **15** |
| Development | 5 | 9 | 3 | 12 | 1 | 1 | 4 | 7 | 0 | 0 | 0 | 2 | 2 | 10 | 3 | 4 | 2 | 0 | 1 | 0 | **66** | **15** |
| Land use + Change | 4 | 15 | 10 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 0 | 2 | 0 | 1 | 0 | 0 | **53** | **9** |
| Region - regional | 6 | 6 | 4 | 4 | 1 | 0 | 1 | 6 | 1 | 0 | 1 | 2 | 4 | 2 | 5 | 2 | 1 | 0 | 1 | 1 | **48** | **17** |
| Local | 5 | 11 | 4 | 3 | 0 | 0 | 1 | 6 | 3 | 0 | 3 | 1 | 4 | 4 | 0 | 1 | 0 | 0 | 1 | 0 | **47** | **13** |
| Supply | 5 | 6 | 5 | 11 | 3 | 0 | 1 | 2 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | **40** | **12** |
| Rural | 6 | 11 | 2 | 3 | 2 | 0 | 2 | 1 | 0 | 0 | 1 | 3 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | **36** | **11** |
| Transport | 8 | 3 | 2 | 3 | 2 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 1 | 0 | 2 | 0 | **32** | **10** |
| Urban | 1 | 16 | 2 | 6 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | **32** | **9** |
| Land(scape) Quality | 5 | 8 | 2 | 0 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 6 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | **31** | **10** |
| Demand | 7 | 3 | 0 | 12 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | **30** | **9** |
| Availability | 1 | 4 | 6 | 5 | 1 | 0 | 1 | 1 | 0 | 0 | 2 | 1 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | **28** | **12** |
| Renewable resources | 8 | 2 | 0 | 9 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | **24** | **7** |
| Planning | 2 | 1 | 1 | 2 | 1 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 1 | 5 | 1 | 1 | 0 | 0 | 1 | 0 | **23** | **11** |
| Strategic Objectives | 2 | 4 | 4 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | **18** | **9** |
| Security | 2 | 5 | 0 | 5 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **15** | **6** |
| Competition | 3 | 3 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **12** | **4** |
| Spatial aspects | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **1** | **1** |
| **Sum of Codes per Strategy** | **76** | **111** | **60** | **99** | **22** | **3** | **15** | **54** | **7** | **0** | **11** | **15** | **31** | **49** | **12** | **23** | **6** | **3** | **8** | **3** | **618** | |

DE-NPS = German National Policy Strategy; DE-RS = German National Research Strategy; FR-ST = French National Strategy; FR-AP = French Action Plan.

**Table A4.** Number of Codes in specific Chapters.

| Strategy / Chapter | (Executive) Summary/ Abstract | Introduction/ Definitions | Vision | Background/ Status | Challenges | Strategic Objectives | Guidelines/ Policy Framework | Measures/ Actions/ Initiatives | Risk Factors | Scenarios/ Prospects | Conclusions | Case Studies/ Examples | Sum | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EC 2012 | | x | | 2 | x | 5 | 54 | 11 | | 4 | | | **76** | [31] |
| EC 2018 | | x | | 26 | | 4 | 5 | 70 | | | 6 | | **111** | [32] |
| AT | | | x | 29 | 2 | 3 | 17 | 9 | | x | | | **60** | [37] |
| DE NPS | 17 | x | x | 25 | 3 | 31 | 9 | 14 | | | | | **99** | [26] |
| DE RS | 1 | | x | x | 3 | 11 | | 7 | | x | | | **22** | [33] |
| DK | x | | | x | | | | 3 | | | | | **3** | [38] |
| ES | | 7 | | 6 | | x | x | 2 | | | | | **15** | [39] |
| FI | x | 6 | x | 27 | | x | | 21 | | | | | **54** | [40] |
| FR ST | | x | | x | | x | | | | | | 7 | **7** | [34] |
| FR AP | | | | | | | | x | | | | | **0** | [35] |
| GB | x | x | x | 9 | x | x | x | 2 | | x | x | x | **11** | [41] |
| IE | | x | x | 6 | | 3 | 3 | x | | | x | 3 | **15** | [42] |
| IT | x | 11 | | 9 | 6 | | | 5 | | | | x | **31** | [43] |
| LV | x | | | 18 | | x | | 26 | 5 | | | | **49** | [44] |
| NL | | 3 | | x | | | 9 | x | | | | | **12** | [45] |
| SE | x | x | | 1 | x | | | 22 | | | | | **23** | [46] |
| OECD | x | | | | 3 | x | x | | | 1 | 2 | | **6** | [13] |
| CA | 2 | x | | | | | | 1 | | | x | x | **3** | [47] |
| NO | 8 | | | | | | | | | | | | **8** | [48] |
| USA | x | | | 1 | | 2 | | | | | x | | **3** | [49] |
| **Codes per Chapter** | **28** | **27** | **0** | **159** | **17** | **59** | **97** | **193** | **5** | **5** | **8** | **10** | | |
| **Strategies per Chapter** | **4** | **4** | **0** | **12** | **5** | **7** | **6** | **13** | **1** | **2** | **2** | **2** | | |

Empty cell = Chapter doesn't appear in this strategy; x = No code in this chapter; 7 = Number of codes per chapter.

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