

Article

Towards a Bioeconomy in Europe: National, Regional and Industrial Strategies

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Abstract: Establishing an advanced European bioeconomy is an important step in achieving the transition towards sustainable development and away from fossil fuels. The bioeconomy can be defined as an economy based on the sustainable production and conversion of renewable biomass into a range of bio-based products, chemicals, and energy. Several strategies have been produced in Europe from different perspectives that outline visions, intentions, and recommendations for the transition to a bioeconomy. An analysis of twelve of these strategies was conducted using a meta-analytical framework. This paper outlines the results of this study covering national, regional, and industrial perspectives on the bio-based economy in Europe. The analysis shows that a common direction for the bioeconomy, based on research and technological innovation in the various applications of biotechnology, is developing in Europe. It highlights the important role that the regional level will play in facilitating collaborations between industries and research institutions needed to foster innovation and optimize the use of biomass. The analysis also identifies that the development of European bio-based product markets are needed for bioeconomy expansion. However, the transition needs to have a lifecycle perspective in order to ensure that an economy founded on biomass is sustainable and equitable.

Keywords: bioeconomy; bio-based economy; Europe; transitions; strategies

1. Introduction and Background

In order to address societal challenges, such as climate change, natural resource scarcity, and unsustainable consumption patterns, a transformative change is needed that involves long-term approaches and interactions at all levels of society. The concept of a bioeconomy represents an opportunity to tackle these challenges and create the transformations needed in socio-technical systems [1]. A bioeconomy can be defined as an economy in which the basic components of materials, chemicals and energy are derived from renewable biological resources [1]. It is closely connected to the agricultural and forestry sectors as well as marine resources and waste management. Essentially, the bioeconomy involves a transition away from the use of fossil-based resources and towards the production of renewable biomass and the conversion of this biomass into food, feed, energy, biofuels, and bio-based products [2].

With an estimated market value of over two trillion Euros, the current bioeconomy contributes significantly to the European economy [2]. This also highlights the importance of the bioeconomy as a central component in shaping sustainable development in Europe. Recent policy strategies established by the European Commission (EC) and the Organisation for Economic Cooperation and Development (OECD) highlight the priority that the bioeconomy and the transition away from a fossil resource-dependent society has taken on the European and international political and economic stage [2,3]. These initiatives have prompted a number of European countries, regions, and industries to create strategies and declare their intentions and visions for the development of a bioeconomy in Europe.

In 2012, based on the conclusions from various European Union (EU) presidency conferences, a number of foresight reports, and a stakeholder consultation process, the EC published a combined strategy and action plan document called “Innovating for Sustainable Growth: A Bioeconomy for Europe” [2]. The strategy aims to offer direction for research and innovation agendas in the bioeconomy sectors, contribute to a more enabling policy environment and pave the way to a more innovative, resource efficient and competitive European society [2]. The actions are based on three key pillars: investments in research, innovation and skills; reinforcement of policy interaction and stakeholder engagement; and enhancement of markets and competitiveness in the bioeconomy sectors. Within these pillars, twelve main actions are established, which include increasing multi-disciplinary research and innovation; creating markets for bio-based products and initiatives through standards and labels; and establishing a bioeconomy panel to increase cross-sectoral collaboration and policy coherence [2,4].

The development of such strategies is an important step toward achieving a bioeconomy transition, particularly as strategies actively structure the problem at hand and indicate the intentions of those involved; thus, they can set in motion the necessary measures needed for change [5]. They are relevant steps in determining the direction that a transition will take, where funding will be placed, and who will be involved. Levidow *et al.* [6] note that the bioeconomy is still a new concept and it is yet to be fully integrated into policy; therefore, the creation of strategies will significantly influence how future priorities for the bioeconomy are defined and policies implemented at all governance levels.

With this in mind, a study of twelve European strategies was conducted that included three produced by national governments, six by regional agencies, and three by industrial groups. The overarching objective of this study was to improve the understanding of the design and development of the bioeconomy in Europe by analysing the various strategies produced by these groups. This paper presents the results of

the study covering national, regional and industrial perspectives on the bioeconomy in Europe. The original study was limited to these twelve case studies, however, to gain a complete understanding of the topic, observations and lessons are drawn from other literature sources and from the European strategy and action plan on the bioeconomy. Furthermore, there has been little focus in the literature on how the bioeconomy is developing at the regional level. Therefore, in this study particular attention is given to regional strategies. Although they vary significantly in scope and in the level of detail, bioeconomy strategies can provide a greater understanding of how the bioeconomy is currently developing in Europe and how it is likely to develop in the future.

It is important to note that as the attention toward the bioeconomy has increased, different understandings and interpretations of the concept have developed. The terms bioeconomy, bio-based economy, and knowledge-based-bioeconomy (KBBE) have all been used when discussing this topic. All these terms essentially describe the same concept; a transition from a fossil fuel based society to one based on the production of bio-based products and energy from renewable biomass, however some differences exist in how these terms are applied. These primary differences are discussed at length by Schmidt *et al.* [7], Birch and Tyfield [8], and Staffas *et al.* [9]. For the purpose of this paper the terms bioeconomy, bio-based economy, and KBBE will be used interchangeably.

2. Approach and Methods

This research consisted of three key steps: the identification of a sample set of national, regional and industrial bioeconomy related strategies in Europe (see Table 1); the development of summaries of each of the selected strategies according to a meta-analytical framework; and a comparative analysis between the various strategy summaries in order to present key similarities and differences and to understand how the bioeconomy is envisioned and applied at different levels of governance.

This paper is primarily descriptive in its nature. This is because it attempts to provide a comprehensive picture of how the bioeconomy is being envisioned and shaped within Europe. However, certain conclusions can be drawn from the analysis of the various strategies, and thus, recommendations for the future development of the bioeconomy can be derived from this research. Interviews were conducted with academics, experts and journalists, all of whom have been actively working on and discussing the European bioeconomy. Interviews helped gain further understanding, insights and opinions into the transition to a bioeconomy in Europe.

Table 1. National, regional, and industrial strategies on the bioeconomy.

Country	Title of document	Author	Year
Sweden	Swedish Research and Innovation Strategy for a Bio-based Economy	Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS)	2012
Germany	National Policy Strategy on the Bioeconomy	German Federal Ministry of Food and Agriculture	2013
Finland	Finnish Bioeconomy Strategy	Finnish Ministry of Employment and Economy	2014

Table 1. Cont.

Region	Title of document	Author or interviewee	Year
Flanders, Belgium	Bioeconomy in Flanders	Government of Flanders Interdepartmental Working Group for the Bioeconomy (IWG)	2014
Drenthe, the Netherlands	Interview	Representative of the provincial government	2014
South Holland, the Netherlands	Interview	Representative of the provincial government	2014
Zeeland, the Netherlands	Interview	Representative of NV Economische Impuls Zeeland	2014
North-Rhine Westphalia, Germany	Interview	Representative of the regional state government	2014
Baden-Wuerttemberg, Germany	Bioeconomy: Baden-Wuerttemberg Path to a Sustainable Future	BioPro Baden-Wuerttemberg GmbH	2013
Industry	Title of document	Author	Year
Energy	Natural Power: Essent and the Bioeconomy	Essent	2013
Forest Fibre	The Forest Fibre Industry: 2050 Roadmap to a Low-carbon Bio-economy	Confederation of European Paper Industries (CEPI)	2011
Biotechnology	Building a Bio-based Economy for Europe in 2020	The European Association for Bio-industries (EuropaBio)	2011

From the literature and interviews, a number of bioeconomy-related strategies within Europe were identified. Out of these, twelve were selected for analysis. These were chosen based on meeting several criteria (see Figure 1) developed specifically for this study. However, the approach toward the regional strategies was slightly different. Regional governments and research institutions that have been actively developing bioeconomy related activities were identified in the initial research phase. Those that had written strategy documents that met the criteria were included in the study. However, very few of the regional documents were published, or in many cases were not available in English. In this case, the data was gathered primarily through semi-structured interviews with authors or representatives from the relevant government departments or regional research institutes.

The strategies vary in terms of approach and level of detail provided regarding the different areas of the transition towards a bioeconomy. In order to extract commonalities and understand differences, each of the selected strategies were analysed according to a framework of specific analytical questions (see Table 2). The purpose of the framework is to develop an understanding of the objectives, priorities and assumptions of each of the different strategies. Results under each of the headings were compared across the different strategies. The comparison helps to create a better understanding of how the bioeconomy is developing in Europe at different scales and across sectors.

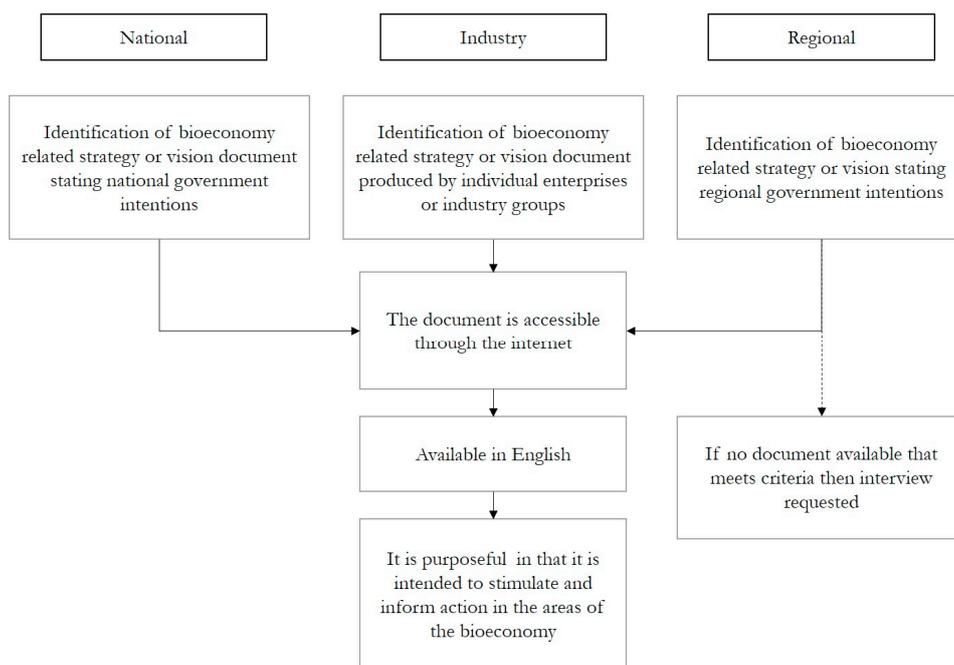


Figure 1. Selection process and criteria for strategies on the bioeconomy.

Table 2. Analytical framework for the bioeconomy (Adapted from Wiseman and Edwards [10]).

Background and Objective	
	Who is responsible for developing the strategy?
	What are the overall aims of the strategy?
	What are the priority areas in the strategy?
Targets and Progress	
	What are the targets set in the strategy?
	How do the strategies aim to measure progress?
Assumptions and Priorities	
Research and Innovation	What assumptions are made regarding research and innovation in the transition to the bioeconomy?
Biomass and Land use	What assumptions are made about the production and use of biomass in the bioeconomy?
	What assumptions are made regarding land use in the bioeconomy?
Economy and Finance	What assumptions are made regarding financing the transition to the bioeconomy?
Governance	What assumptions are made about governance mechanisms and arrangements?
Societal Change	What assumptions are made about behavioural, societal, and political transformation?
	What assumptions are made about ensuring an equitable and sustainable transition?

The analytical questions are adapted from a framework developed by Wiseman and Edwards [10] to analyse eighteen large-scale post-carbon strategies and pathways. Although some questions were taken directly from the framework, not all questions were considered relevant to the bioeconomy. Therefore, by consulting the literature, the framework was adapted to encompass central aspects of a bioeconomy;

mainly to include assumptions on research and innovation, and biomass and land use change. Additionally some of the headings were changed in order to better represent the questions being put forward in the context of the bioeconomy.

The meta-analytical framework for post-carbon strategies and pathways and this study on the bioeconomy share several characteristics and objectives. First, both attempt to gain an overview of the way in which different actors are portraying transitions. Second, the transitions described for the bioeconomy and post-carbon strategies and pathways will require system-wide changes involving society, governments and industry. Third, both aim to compare the strategies in order to extract key commonalities and differences.

3. Analysis and Discussion

The comparative analysis produced the following key assumptions and priorities for the development of the European bioeconomy and highlighted some important lessons and implications. The analysis covers five key areas including research and innovation, biomass and land use, economy and finance, governance, and social change. These areas are separated here but in reality there are strong connections between all these areas and for the European bioeconomy as a whole.

3.1. Research and Innovation

Supporting research and innovation features as a primary component of the EC strategy and action plan for the development of the bioeconomy and it is clear from the various analysed strategies, that it will form the basis of the transition. The need to create a strong knowledge base that supports innovation and drives the development of the bioeconomy is reflected in the national, regional as well as the industrial strategies. They all describe the importance of the role that research and innovation will have in a strong bioeconomy and include, to some extent or another, measures that are aimed at supporting research and fostering innovation.

A key aspect that runs through all the strategies is the inclusion of measures that aim to bring research institutions and industry together. When research and industry come together and collaborate, this is when innovation can occur [11]. All strategies highlight the crucial need for collaboration between sectors, however, it is primarily at the regional level where these interactions happen. The regions analysed focus heavily on fostering innovation by bringing all the actors (at the regional and national levels) involved together through the development of research programmes, innovation networks and the formation of industrial and research clusters.

Asheim and Coenen [12] state that the regional dimension is crucial for nurturing innovation. They note that it is at this level where networks and clusters of SMEs, industries and research institutions are able to develop, and knowledge spill-over can occur. Furthermore, Doloreux and Parto [13] indicate that each region has its own strengths and resources, and that these are very important in stimulating their innovation capabilities. In fact, an important difference between the regional strategies on the bioeconomy is that each point to their particular strengths and capabilities as an important factor in determining focus areas.

Patermann [14] highlights that each region has its own capacities, in terms of industry, agriculture, and university presence, therefore the development of the bioeconomy in regions will be highly contextualised. For example, the strengths of North-Rhine Westphalia lie in pharmaceutical engineering,

chemistry and biotechnology; their approach is therefore heavily focused on developing bio-based initiatives in these areas [15]. South Holland on the other hand has a large horticultural presence and strong chemical industries; their focus is on developing the uses for various plant derivatives, as well as developing bio-chemical applications [16].

These differences in regions present an important opportunity for inter-regional collaboration. Many of the regions have already begun to collaborate, both nationally and internationally. For example, South Holland and Zeeland are both partners in the bio-based Delta, together with the province of North-Brabant [16,17]. Each of these regions have a number of strong industrial, chemical and agricultural clusters, as well as a large concentration of research centres. The bio-based Delta brings these different sectors together with the various governments in order to coordinate projects, funding and knowledge transfer. For major changes in a bioeconomy to occur, collaboration between the different regions is fundamental.

Although many of the regions have different priorities in terms of specific fields of research, a key theme that runs through all the analysed strategies is the focus on biotechnological and life science solutions for developing the bioeconomy. The research agendas of the national and industrial strategies are dominated by industrial biotechnology. The focus is on developing conversion technologies, expanding bio-refineries, exploring novel ways of using biological feedstocks and developing bio-based products through biotechnological research. For example, the Swedish strategy aims to focus research on developing smarter uses of raw materials through research into biorefineries and on intensifying the production of biomass through research into new and improved biomass properties [18]. Similarly, the German strategy points to the importance of supporting research that fosters the development of technologies to enhance the provision and quality of renewable biomass [19]. This is mirrored by the industrial strategies that call for support into technological research, particularly into the advancement of bio-refineries. The industrial approaches in particular state that a successful transition to a bioeconomy will require advancements in industrial biotechnology; this can only come about by focusing research and innovation into these areas.

3.2. Biomass and Land Use

Biomass is the foundation of the bioeconomy and the way in which it is produced and utilised will have an important effect on the sustainability of the transition. The EU 2020 strategy calls for smart, efficient and sustainable growth [20]. The sustainable and efficient utilisation of biomass in the bioeconomy will be important in achieving this goal. A central theme that runs throughout all the strategies on the bioeconomy is the need to optimize the use of biomass by ensuring that, at each stage of its use, the highest possible value is gained from it. The strategies highlight two measures aimed at ensuring the most efficient and complete use of biomass along the value chain. These are the application of the cascade principle and the utilization of waste and agricultural residue streams.

The cascading principle (see Figure 2) is considered to have an important role in ensuring that biomass is utilized initially for high value applications, such as in the production of bio-based products, and then recycled and re-used before being converted into an energy source [16,21]. Keegan *et al.* [16] argue that cascading the use of biomass can substantially improve resource efficiency as it fulfills both material and energy needs from the same feedstock. Although in principle promoting cascade utilization is considered a priority in most strategies, the regions of Drenthe and South Holland note that in reality, it

can be quite difficult to implement, particularly when the application of biomass for energy is more advanced and holds a greater demand [16,22].

In fact, Carus *et al.* [23] remark that there is no level playing field between high and low value applications of biomass in EU policy. Despite studies that show that the potential benefits of the material use of biomass, in terms of employment and added value, are greater than those from biomass for energy, the current EU policy framework is pushing the utility of biomass toward the production of biofuels [23]. Carus *et al.* [23] argue that these policy priorities can distort the market towards the use of biomass for energy applications, rather than toward higher value-added material uses. In comparison to biofuels, there are very few European incentives for the production of bio-plastics and bio-chemicals [11]. It is worth noting that the cascade principle can be interpreted in different ways, such as in monetary value, function, or space.

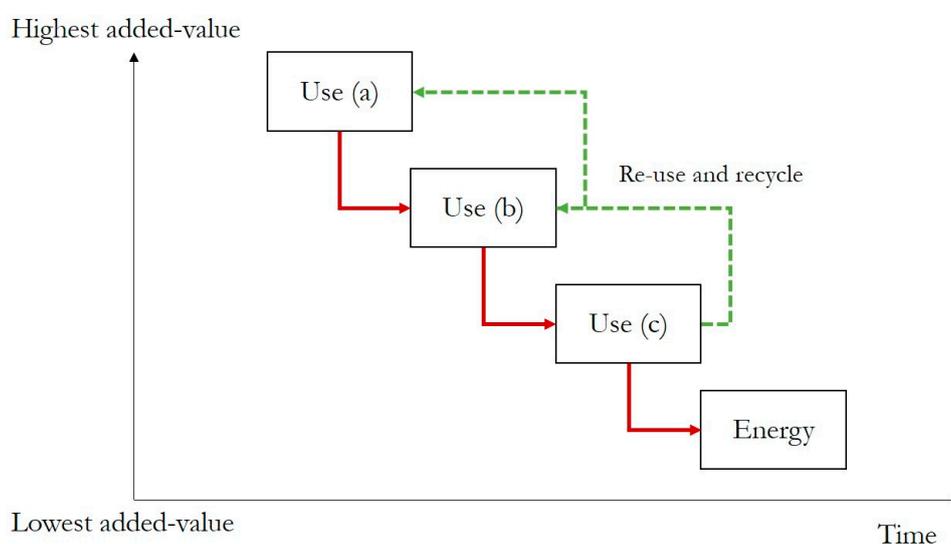


Figure 2. Cascading use of biomass in the bioeconomy (Adapted from Sirkin and Houten [24]).

The other measure considered important for optimizing the use of biomass in the bioeconomy is the exploitation of waste and agricultural residue streams. The various regions in particular, focus on bringing industries and enterprises together to create opportunities for the utilisation of waste streams and agricultural residues for bio-based activities. The regional innovation networks in the North-Rhine Westphalia and the bio-based Delta partnership for example, are regional programs that aim to support strategic partnerships between industries and enterprises in order to maximise the utilization of biomass. The industrial strategies also call for investment in regional infrastructures to ensure the most complete use of biomass, including waste-based raw materials.

The development and demonstration of flagship technologies and biorefineries will also be vital for the future development of the bioeconomy in Europe [14]. This issue appears in the various strategies, especially at the national and industrial level. The development of integrated biorefineries will be crucial for ensuring the high value utilization of biomass and its development into high quality bio-based products. Despite the opportunity for development of biorefineries at the regional level, with the local connections to waste streams and the presence of industrial clusters, it did not appear a crucial priority in regional strategies.

Another priority that appeared throughout the national and regional strategies, is that above all, the production of food and feed must take precedence over the use of biomass for material or energy purposes. Many strategies note that the development of the bioeconomy should not come at the expense of food security. The German and Swedish strategies include measures that aim to resolve and avoid conflicts between land use options. They also highlight the need to avoid the material or energy use of biomass affecting food security [18,19].

Competition between land use is an important area of discussion, which often revolves around the issue of direct competition of the use of biomass for food or non-food applications. However, Carus and Dammer [25] explain that the debate on ensuring food security is based on arable land availability rather than crop use. They argue that all kinds of biomass should be accepted for industrial purposes, especially food crops. Food crops are more land efficient than non-food crops and more importantly, in times of crisis they can be reallocated to ensure food supply. This is not possible with non-food crops that only have the function as an industrial input [25].

The import of biomass from outside of Europe is also discussed as an important source of input. In particular, Essent [26] and CEPI [27], note that cheap imported biomass will play a crucial part of the bioeconomy. The presence of significant ports in Europe means that the infrastructure and logistics already exist for the movement of large amounts of biomass. BMEL [19] explains that Germany already imports large amounts of biomass for various uses, however ensuring the sustainability of these imports is paramount. The national and industrial strategies state that there is a need for the creation of international standards and certification to ensure that imported biomass is sustainable.

3.3. Governance

The key governance issue that cuts across the EU and national strategies, as well as the industrial strategies is the necessity to create a coherent and supportive policy framework for the development of the bioeconomy. The industrial strategies provide policy advice and recommendations focused at the EU level; they highlight the need for the EC to ensure supportive and regulatory policies that create a level playing field for all actors. They emphasise the need for policies that facilitate the collaboration between all actors involved, that support the development and demonstration of bio-based technologies and products and that help stimulate market demand for these bio-based products. They also call for financial support for bio-based activities and coherence among other EU policies, particularly related to the EU 2020 strategy.

These supportive measures identified in the industrial strategies seem to be in agreement with the actions proposed by the EU, national and regional strategies. Five main actions to help develop the necessary framework for the development of the bioeconomy are present within all these strategies. These include creating measures that aim to increase coherence between different policy sectors; creating measures for facilitating the cooperation between government, research institutions and industry; increasing communication to society on bio-based activities; implementing measures that support the creation of new markets and the uptake of bio-based products; and facilitating the development and demonstration of bio-based activities through financial and administrative support.

Creating coherence between different policy measures is a key issue for the bioeconomy, particularly as many different policy areas influence it. In the context of transitions, Loorbach [28] states that institutional

fragmentation and incoherence are major barriers for integrative long-term governance. The EC strategy and action plan on the bioeconomy included the creation of the European bioeconomy panel, which aims to address inconsistencies within EU policy, as a means to overcome these barriers. The bioeconomy panel has highlighted the importance of policy coherence both within the EU and between policies at the national and regional levels. They proposed the creation of regional interdepartmental bioeconomy panels to maximise collaboration and coherence [29].

This is reflected at the national and regional levels, where coordination between the various ministries and departments is a key issue. The German strategy, for example, aims to develop an inter-ministerial bioeconomy working group specifically to address policy coordination and improve coordination with the various regions [19]. This is, replicated at the regional level where North-Rhine Westphalia have set up an inter-ministerial exchange platform to improve coordination between departments [15].

Furthermore, the formation of research and industrial clusters and the development of public private partnerships are considered important steps toward enhancing collaboration, ensuring coherence and fostering innovation in the bioeconomy. The German cluster called Industrielle Biotechnologie 2021 (CLIB2021), for example, connects SMEs, industries and research institutions together to support and initiate new bio-based research and business projects, as well as to identify new value chains, improve access to funding and support research and development [30]. At the EU and national levels, the development of public private partnerships helps facilitate cooperation between government, industries and research institutions. Public private partnerships (PPP), such as the Bio-based Industries Consortium (BIC) and the Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) PPP, bring key industry stakeholders together with research institutions and governments to address key investment, research, innovation, and policy issues. The aim of these clusters and partnerships is to enhance cooperation and support the development of innovative technologies and bio-based solutions, to help Europe move toward a low carbon, resource efficient and competitive future [31,32].

Five of the six regional strategies have established platforms and groups to improve communication between these various actors, such as South Holland's bio-based delta platform [16] or Baden Wuerttemberg's bioeconomy expert network [33]. The regional strategies highlight the facilitating role that regional governments play in the bioeconomy by providing the means for industries, research institutions and enterprises to find each other and create the necessary partnerships needed for growing the bioeconomy. Additionally, they note the importance of involving and communicating with all stakeholder groups, particularly civil society; a feature found in all analysed strategies. Increasing public awareness of the presence and benefits of bio-based activities and products is important in helping create markets and stimulate demand for them. Developing communication actions to inform the public and increase awareness are important measures of the regional strategies

The need to create markets and facilitate the uptake of bio-based products is an important feature of all strategies. The regional strategies in particular, highlight that public procurement is an important tool in stimulating bio-based markets and creating demand for bio-based products. The strategy by the Province of Drenthe, for example, notes that the regional government must act as a "launching customer" for bio-based products and innovations, through public procurement and tendering of products and bio-based projects [22]. Although the Finnish strategy includes measures for increasing the uptake of bio-based products, of which public procurement is a key, the German and Swedish strategies have not emphasised this

point [18,19,34]. Instead, these national strategies seem to place a greater importance on accelerating the commercialisation of bio-based solutions and bridging the gap between research and the market.

The EC strategy and action plan on the bioeconomy notes the importance of public procurement, but emphasises the need for developing standards and labels for bio-based products in order to facilitate it. Carrez [11] notes that in order to facilitate uptake of bio-based products, consumers need to be able to recognise them. Although some regional and national strategies mention this briefly, it is primarily at the European level that it is discussed. The EC strategy and action plan states that it is taking an active role in developing labels, standards and certification for bio-based products, particularly through supporting the KBBPPS (or knowledge based bio-based products pre-standardization) and open-bio projects; these aim to provide the information and methods in order to create standards for bio-based products [35,36].

Another important observation from the analysis of strategies is that, apart from the Finnish strategy, the development of measurable targets or means of measuring the progress of the bioeconomy has received little attention at the national level. Some strategies include measures such as developing progress reports, however only the Finnish strategy has identified indicators that will allow them to clearly measure the progress of implementing the bioeconomy. Staffas *et al.* [9] state that “it is fundamental to the success and sustainability of the bioeconomy that measurement for progress are defined and applied.” This remains a major challenge for research institutions, industry and government.

3.4. Economy and Finance

An important instrument in accelerating the commercialisation of bio-based solutions is providing financial support. The EU, national and regional strategies all suggest that providing subsidies and funding for innovation and bio-based activities is a key to supporting the development of the bioeconomy. The national strategies indicate that funding will be made available for supporting research and innovation, commercialisation of projects and for the business development of new innovative SMEs.

The EU has made funding available for these activities through the Horizon 2020 Programme and various other schemes such as its structural funds [37,38]. These structural funds are of particular interest to the various regions, as they are able to co-fund research and innovation projects [11]. In fact, the regional strategies note that the majority of funding for bio-based activities in the regions comes from EU or national funding programs and that the Horizon 2020 Programme will also play a significant role in supporting innovation and investments in the bio-based economy in Europe.

Smart, targeted funding is important for the development of the bioeconomy, especially for the commercialisation of bio-based technologies and products [11]. In order for the uptake of bio-based products to occur, they must be price competitive compared to current products on the market. In order to become price competitive the technology needs to reach maturity and the products need to reach a certain volume [11]. There are many factors involved in making bio-based products and technologies competitive.

The Lead Market Initiatives Advisory Group for Bio-based Products state that EU and national governments must develop financial incentives for the production of bio-based products, as well as the conversion of production plants and industrial processes [39]. They recommend the development of incentives such as taxation, grants and state aid measures to support this change. They also note that the EU structural funds need to be made available to the development of these products and technologies.

The Lead Market Initiatives established in the EU help to identify markets that are highly innovative, provide solutions of broader strategic, societal, environmental, and economic challenges, and rely on the creation of favourable framework conditions through public policy measures.

3.5. Societal Change

An important aspect that features across the national and many of the regional strategies is the need for a transformation in the mind-sets of society, industries and governments. They note that a transition to an economy predominately based on biomass will require the cooperation of all sectors of society and a change toward sustainable consumption and production patterns, both on the demand side and supply side of the economy.

As a means of addressing the inefficient use of natural resources in industry, many of the strategies promote the cascade principle and the utilization of waste streams. Keegan *et al.* [21] state that the use of the cascade principle can reduce consumption of raw materials in industry, as multiple material and energy needs are met from the same feedstock; it creates a more resource efficient use of biomass, where more value can be gained from less feedstock. Similarly, cooperation between industries in terms of waste and residue utilisation can create circular flows of materials and energy, which again can lower the consumption of raw materials by industry [15].

A number of the national and regional strategies highlight that increasing dialogue with the public is crucial for addressing the issue of over consumption in society. The German strategy for example, includes measures aimed at addressing consumer behaviour by providing information on sustainable consumption and food waste [19]. It also has a number of initiatives that aim to create awareness around these issues. The Swedish and Finnish strategies highlight the importance of communicating the benefits of the bioeconomy and bio-based products to society as a means of shifting consumption away from fossil-based products toward more sustainable bio-based products [18,34].

The need for a whole systems perspective for the development of the bioeconomy is another important issue that some of the strategies highlight. The Swedish strategy for example, notes that in order to achieve a sustainable bioeconomy and reduce societal consumption levels a life cycle perspective is needed for the production and consumption of bio-based products [18]. For example, a life cycle perspective would be important in order to implement a production system based on the cascade principle; where the end-of-life of one product becomes the raw material for the next. Furthermore, this system would require the active participation of consumers and adequate recycling infrastructure. Patermann [14] notes that the use of biomass is not inherently sustainable, the impacts of the whole system from production to consumption needs to be considered. This can be particularly true in the case of biomass imports.

The industrial strategies together with some of the national strategies argue that the large-scale import of biomass will be necessary for the development of the bioeconomy. However, they call for the development of standards and certification schemes to ensure its sustainability. More importantly, they state that the import of biomass for industrial purposes must not have negative social, economic, or environmental impacts in the producing countries, above all it must not impact food security. The German strategy includes this point as a guiding principle in its strategy [19].

As outlined above, the various strategies address the need to transform societal and industrial mind-sets in order to achieve a sustainable transition to a bioeconomy. A bioeconomy based on technological

fixes; where fossil fuels are simply replaced with biomass, does not actively provide the behavioural changes required to address the fundamental issue of over consumption [40]. Furthermore, a bioeconomy system focused on industrial efficiency, that emphasises continued economic growth and competitiveness, is in danger of simply maintaining the same consumption system as the fossil-based economy does today [41].

4. Conclusions and Reflections

The aim of this paper is to provide a better understanding of how the bioeconomy is developing in Europe by analysing twelve strategies produced by national governments, regional agencies and industry groups. The paper also draws insights from the European strategy and action plan on the bioeconomy, as well as from interviews with experts and stakeholders. It is important to note that the strategies differed in how much detail they provided; therefore, the analysis sought to gain a broad overview of the assumptions and priorities made by these strategies, rather than focus on technical details. The findings show that the different strategies focus on the same key priority areas for developing the bioeconomy. These include fostering research and innovation, primarily in the field of biotechnology; promoting collaboration between industry, enterprises and research institutions; prioritising the optimized use of biomass by implementation of the cascade principle and by utilising waste residue streams; and providing funding support for the development of bio-based activities.

These priorities are forming the basis of an advanced bioeconomy in Europe and it is clear that a particular direction for the bioeconomy is developing. There is a strong push toward a European bioeconomy founded on supporting sound scientific research and technological innovation, particularly in the development of new biotechnological and industrial solutions for optimising the use of biomass. Central to this will be the development and demonstration of biorefineries, especially as a means of facilitating the cascading use of biomass and advancing the growth of bio-based products.

The strategies point to the need for strong collaborations between research institutions and industry in order to facilitate technological innovation. They also suggest that the development of specialized clusters, particularly at the regional scale, will be important in order to aid knowledge and technology transfer, foster innovation and allow for the efficient use of resources. Inter-regional collaboration will have a particularly important role, especially as each region is highly contextualized and specialized in terms of its focus. Collaboration amongst them will be necessary in order to create a holistic and functioning European bioeconomy. Patermann [14] notes that “you do not have just one bioeconomy, but many working together”. Despite the strategies understanding the need for collaboration, there is still a lack of communication between stakeholders as to the activities that are being carried out in different regions and countries; this will need to be addressed in order to achieve a transition.

The strategies acknowledge that the role of the EU and national governments is important in providing the necessary funding programmes and a coherent and facilitating policy framework to encourage the development of the bioeconomy. However, Carus *et al.* [23] noted that there is still an insufficient level of coherence in many EU and national policies, especially in terms of biomass use. For example, the EU renewable energy directive as well as some national energy policies are incentivising the use of biomass as an energy source, where as there is almost no political or financial support mechanism for the industrial material use of biomass. Carrez [11] and Carus *et al.* [23] argue that a stronger policy and funding

framework will need to be established to rebalance the playing field between these uses of biomass. If a bioeconomy based on efficient use of natural resources is to be successful, these inconsistencies will need to be resolved. However, Faaij [42] argues instead, that continued attention needs to be placed on ensuring that the use of biomass for energy plays an integral role in energy, agriculture, forestry, waste and industrial policy. Faaij [42] explains that bioenergy is a much needed renewable energy source that will be a crucial component of the transition away from the use of fossil fuels; therefore, EU policy will need to continue to support its development.

The analysis also showed that the development of new markets and the uptake of bio-based products is likely to be an essential aspect of the bioeconomy. This was highlighted as a key focus area in the Finnish and regional strategies, where measures, such as the use of public procurement and tendering for bio-based products, were included in order to stimulate market demand. Despite the attention given to this aspect at the regional level, it is not a priority area in all national policies. This research suggests that national governments should be working toward facilitating the uptake of these products, which needs to be reflected in their strategies and policies; shaping national public procurement policy toward bio-based products and increasing the awareness of consumers to the benefits of these products would be important first steps.

Overall, there seems to be consensus regarding what needs to be prioritised and included in the transition to a bioeconomy. The various national governments, regional agencies and industry groups are all working toward a similar vision. However, it is important to note that this vision based on the industrial use of biomass is not without criticism. Levidow *et al.* [6], Schmidt *et al.* [7], and Birch and Tyfield [8] state that a bioeconomy based on agro-industrial solutions is too narrow and that it needs to be expanded to include alternative forms of agriculture, greater social and community based innovation and the use of knowledge from farmers as an important means of adding value to biological resources.

Given that all the strategies appear to agree on this current direction for the bioeconomy, it seems unlikely that the bioeconomy in Europe will radically change onto another path. However, these alternative visions should not be disregarded, instead there needs to be further work into integrating alternative forms of agriculture and greater social innovation into the development of the bioeconomy in Europe. The vision by Luoma *et al.* [43] of a distributed bioeconomy could present a more achievable alternative path, where the positive relationships that localized industry can have with community-based enterprises are exploited at the regional and local scale. This presents a bioeconomy that is more in line with the European strategies, but also has a greater focus on community involvement. In fact, the Finnish strategy is promoting a more decentralized and regional focus for its bioeconomy transition.

The importance of ensuring sustainable production and use of biomass may be a defining factor that shapes the bioeconomy as it develops in Europe. It is important to note that although sustainability links closely to the bioeconomy, it is not an implicit result of the bioeconomy; just because the bioeconomy is based on renewable resources, it does not make it inherently sustainable. Pfau *et al.* [44] argue that it is important that as the bioeconomy develops, the relationship with sustainability is taken into consideration. The use of tools such as lifecycle assessments should continue to be explored so that a significant contribution to sustainability, from the various activities in a bioeconomy, can be reached. A lifecycle perspective is needed in the development of the bioeconomy to understand the implications that the activities within it may have and to minimise any negative social, economic or environmental impacts in Europe and abroad.

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Author Contributions

Matteo de Besi and Kes McCormick conceived and designed the research. Matteo de Besi undertook the primary research and analysis of the data. Both Matteo de Besi and Kes McCormick wrote the paper. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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