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Resources, Collaborators, and Neighbors: The Three-Pronged Challenge in the Implementation of Bioeconomy Regions

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Received: 13 November 2019; Accepted: 14 December 2019; Published: 17 December 2019



Abstract: Over the last decade, the bioeconomy has become increasingly important and visible in international policy agendas, with several strategies being recently developed. The implementation of bio-based technologies mostly takes place on a regional scale. Therefore, from a regional perspective, a key question revolves around what main challenges are associated with technological developments that could catalyze the implementation of sustainable bioeconomy regions. In this study, a cross-cutting analysis was carried out to determine these challenges. First, interviews were conducted with industry practitioners and scientists working in the bioeconomy field. These interviews were supplemented with a literature review to determine the status quo of bioeconomy strategies and their implementation, particularly on a regional level. A multidisciplinary workshop was then organized to identify the most relevant challenges in the short- and mid-term associated with establishing bioeconomy regions. The results show that there is a three-pronged challenge in innovative technological development from a regional perspective: (1) Resources: The establishment of sustainable regional feedstock strategies and supplies for supporting the bio-industrial sector; (2) collaborators: The establishment of a regional “critical mass” by fostering supply chain clusters and networks; and (3) neighbors: Understanding the local dynamics of societal trends and preferences and social acceptance of bio-technologies and their representative bio-based products.

Keywords: bioeconomy; systems assessment; regional management; life cycle thinking; regional bioeconomy; innovation; technological development; technological assessment

1. Introduction

Over the last decade, several bioeconomy strategies have been established within Europe and globally, each defining their national and international visions and actions directed toward achieving a bio-based economy. Currently, more than 50 national policies related to the bioeconomy, either as dedicated strategies or bioeconomy-related strategies, have been created, which represents an increase of over 30% from 2015 [1–5]. There are several common key aspects to these strategies: National and global food security, sustainable agricultural production, healthy and safe food production, the industrial application of renewable resources, as well as the further development of biomass-based energy carriers. However, the implementation of these strategies will be challenging, as it relies on the optimized use of available biomass resources.

This optimization is achieved, first, through the introduction of a hierarchical prioritization of end uses (i.e., biomass to produce food, fine and bulk chemicals, as well as materials and energy). Secondly,

it is achieved through the synergic integration of industrial sectors to produce high value-added products. These synergetic uses introduce the concepts of “coupled production systems” (e.g., biorefineries) and “cascading” (i.e., enhancing the use efficiency of a resource through successive upcycling/recycling of the same resource for the production of additional products and to end its life cycle with a final energetic use) [6]. In this way, the use of available natural resources is enhanced. Finally, it is important not to forget that the bioeconomy is not confined to the industrial sector. As soon as the final bio-based products reach consumers, they become part of urban systems and are thus part of the inventory associated with urban metabolism. For this reason, it is important to highlight that, for the bioeconomy to be a real phenomenon, there must be a common effort in the implementation of bioeconomy and circular economy strategies. Only this can ensure the appropriate circularity of the overall system through the closing of the gap between customers and industries by producing sufficient and high-quality secondary raw materials to be fed back into the bio-based manufacturing and industrial sectors [7–10].

Putting the concepts of cascading and coupled production into practice is particularly relevant for bioeconomy strategies, where the demand for feedstock is high and also requires multiple associations between the industrial and manufacturing sectors. It is expected that establishing clear concepts and goals for a sustainable bioeconomy will encourage greater linkages across different industrial and production sectors and thus help to establish integrated bioeconomy networks [11,12]. The identification of the key technical and technological alternatives that encourage these integrated bioeconomy networks will therefore be a major step in the right direction [13,14]. This will not be an easy step due mainly to the broad bioeconomic concepts, which involve a great diversity of industrial sectors influenced by a large set of stakeholders and interests groups [15]. Figure 1 provides a simplified overview of the traditional technological innovation cycle, as well as the role and potential point of influence for several important stakeholders within such innovation cycles. These cycles are also relevant for fledgling bioeconomies.

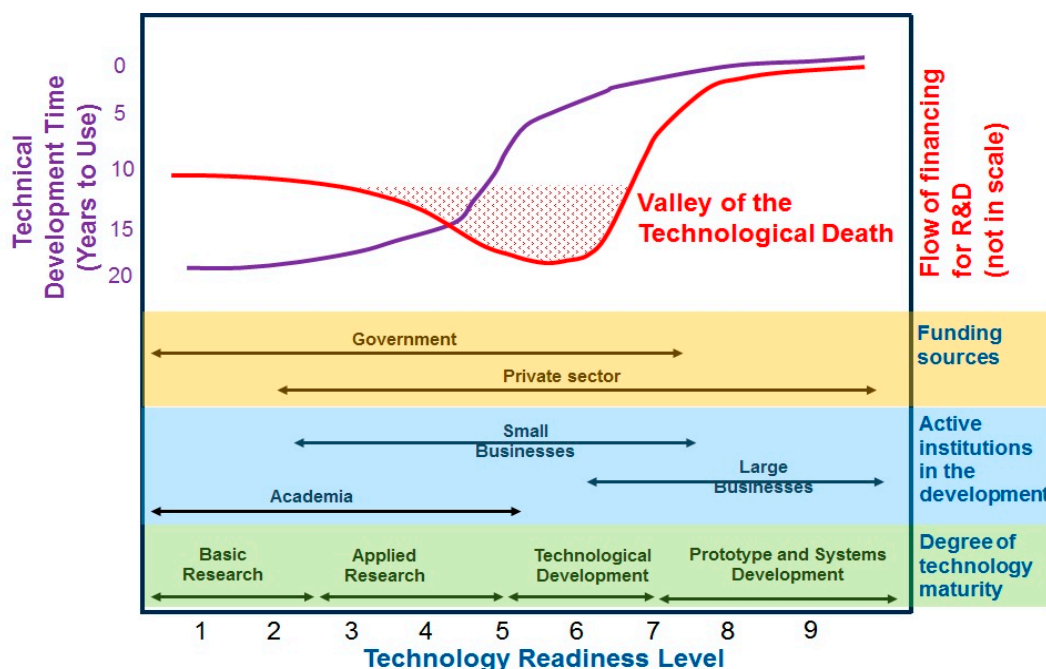


Figure 1. From idea to reality: Overview of the different stages in the technology development cycle, a representation of the roles of stakeholders involved in the development process (active institutions and funding bodies), and the time and costs associated with each development stage (adapted from [16–19]). We use here the technology readiness level (or TRL) concept, as defined by NASA (see [20]) to represent the evolution of the degree of technology maturity from a concept or idea (TRL 1) to its implementation as a product in the market (TRL 9).

It can be observed that many technologies are initiated by academics and/or by small innovative companies, supported (mainly) by national and regional research funding bodies. In this phase, such technologies are deemed to be still at the “basic research” stage. At the end of this basic phase, they are ready to be considered for the next steps of development, i.e., the “applied research” and the “technological development” steps. However, it is at this point that the financing of novel technologies is hindered due to the large uncertainty and risk associated with the technologies’ feasibility and to the higher costs required to bring the technology to the next “readiness level” [16,21]. For many technologies, after the “basic research” phase, financial support is withdrawn or becomes insufficient for the technology to progress to the next phase of development. This is why this point in the technology development cycle is called the start of the “valley of technological death” [17,21]. Technologies that overcome this “valley” generally show both financial and technological feasibility in their basic, applied, and technological development phases and are therefore financed for further development in their implementation phase (i.e., the prototype and systems development). This final phase is mainly found in larger private companies.

An interesting conclusion to be derived from Figure 1 is that, in order to avoid the unnecessary “death” of potentially suitable technologies that could support a bioeconomy, important regional conditions (e.g., biomass resources, local infrastructure, and industrial facilities) and requirements (e.g., potential markets and the availability of workers for certain technologies) would need to be identified in a timely manner. To do this would lead to the challenge of assessing the entire bioeconomy supply chain concepts, which goes beyond the simple assessment of the new technologies. Such an assessment would need to include enhanced economic, environmental, social, and organizational processes [22]. It can be argued that such assessments of bio-based systems should be carried out at a regional scale, because it is at this level that the appropriate mainstreaming of novel bio-technologies and bio-based products must take place to complement the existing industrial infrastructure [12,23,24].

This work, therefore, aims to bridge this information gap from a regional perspective by identifying the major challenges for the timely incorporation of technologies into the existing regional infrastructure, as well as the potential impacts of such implementation, which will encourage the development of regional bioeconomies. The solutions to these challenges will be unique to each region and are therefore outside the scope of this work. This work sets the basis for a discussion within and among regions about how to address the identified challenges and opportunities.

2. Materials and Methods

To identify the major challenges and opportunities associated with different technologies, which could help support the development of regional bioeconomies, a two-step approach was carried out.

The first step involved a bottom-up (expert interviews) and top-down (literature review) analysis to determine the status quo of bioeconomy strategies and the implementation of such bioeconomy strategies, particularly at a regional level. This was conducted across three major dimensions of the bioeconomy system (biomass resources, integrated technology systems, and product and social acceptance).

In the second step, a multidisciplinary workshop was organized in order to identify the major hurdles and challenges that exist in relation to conducting sustainability impact assessments (environmental, economic, and social) of these bioeconomic systems.

2.1. Analysis of the Bioeconomy System: Literature Review and Expert Interviews

In order to better understand the influence that technological innovations and hurdles (Figure 1) can have on the development of regional bio-based economies, an analysis was conducted across the three major dimensions of the bioeconomy system. These were: (1) Biomass resources, (2) integrated technology systems, and (3) product and social acceptance. In order to also generate a more complete picture of the status quo of these bioeconomy dimensions, both a bottom-up (expert interview) and top-down (literature review) analysis was carried out.

For the bottom-up analysis, expert interviews were conducted, during which a series of questions (Table 1) were discussed with industrial and scientific partners (see acknowledgements). The review was conducted using key search terms during the analysis of the expert interviews (Table 2). The search was confined to the years 2010–2019 and was not limited geographically (i.e., it was not focused on a particular country or region) in order to capture the current scientific and practical discussion on the state of the art. Moreover, it must be noted that, although a thorough search was carried out, the intention of this work was not to present a review paper but rather to synthesize the state of the art in order to complement the discussions and interviews.

Table 1. Overview of the questions discussed in the three major dimensions related to technological implementation, as defined in this study.

Addressed Dimension	Driving Questions for the Bottom-Up Analysis
Biomass resources	<ul style="list-style-type: none"> • What is the actual availability of local biomass resources for supplying the bio-based industries? • How can we allocate the available biomass to the different industrial and manufacturing sectors present in the region?
Integrated technology systems (Collaborators)	<ul style="list-style-type: none"> • Are the regional capacities sufficient to implement and achieve the envisaged goals of the bioeconomy strategy? • What will be the key enabling technical developments in the coming years?
Product and social acceptance (Neighbors)	<ul style="list-style-type: none"> • What are the societal trends that influence the mainstream of bio-based products in the markets? • What are the impacts of implementing the envisaged national action lines on the regional development?

Table 2. Keywords used as search terms for the literature review.

Addressed Dimension	Search Terms
Biomass resources	Biomass, agricultural systems, forestry systems, wood-based bioeconomy, sustainable resources management, resources competition, regional analysis, regional impacts, environmental assessment.
Integrated technology systems (Collaborators)	Prospective technologies, technical analysis, innovation, technological development, biorefineries, bio-based technologies, biomass scenarios, bioeconomy scenarios.
Product and social acceptance (Neighbors)	Social acceptance, innovation, business models, regional strategies, governance, regional development.

2.2. Workshop: Identifying Key Questions for Assessing the Impacts of Regional Bioeconomies

An interdisciplinary group of approximately 25 scientists from a diverse range of disciplines relating to the bioeconomy (biotechnology, environmental sciences, microbiology, political sciences, economy, and systems analysis) were requested to identify the most relevant scientific questions when tasked with assessing the potential sustainability and impacts of regional bioeconomic concepts. With such key questions helping us to understand from a system perspective what could be the hurdles for

establishing a regional bioeconomy, the discussion took place in three working groups with a series of questions derived from step one to frame the conversation within each discussion group (Table 3).

- The first working group discussed the nexus between technology and biomass resources, especially in regard to assessing the way innovations in the bio-based technological field are developed and the implications that these technical innovations have on the available biomass resources;
- The second working group addressed the issues on the quandary of scales. In this group, it was discussed how to identify appropriate system limits for assessing the effects of implementing a regional bioeconomy and what restrictions occur when dealing with a higher resolution than a national scale;
- Finally, the third working group discussed land use assessment—a cornerstone for evaluating the bioeconomy. The goal of this discussion was to identify the questions that could help in understanding the environmental and socio-economic impacts of the bioeconomy in terms of land use issues.

Table 3. Questions discussed in the three working groups (aspects to be assessed) of the multidisciplinary workshop on the bioeconomy and biomass resources.

Aspects to Be Assessed	Questions for Framing the Discussion
The nexus between technology and biomass resources	<ul style="list-style-type: none"> • What and where are the information gaps to characterize the interaction between technologies and biomass resources? • What are the challenges to overcome them?
The quandary of scales	<ul style="list-style-type: none"> • Is a region sufficient to capture the burdens of potentially emerging biomass and bioeconomic systems? • With different fragments of the puzzle, can we piece them together to make a holistic picture? • As a consumer, what would be your considerations or reservations before buying a bio-based product?
Land use assessment—a cornerstone for evaluating the bioeconomy	<ul style="list-style-type: none"> • What are the aspects that should be included in the land modelling to evaluate the bioeconomy implementation on a regional scale? • What are the research needs for sustaining that modelling?

Additionally, in a plenary session, the issues discussed within the individual discussion groups were jointly discussed in order to prioritize the most relevant questions that need to be addressed in relation to present and future bio-based systems.

3. Results

3.1. Analysis of the Bioeconomy System

The combined results of the bottom-up (expert interviews) and top-down (literature review) analysis are presented in the following sections, according to the three assessed dimensions (biomass resources, integrated technology systems, product demand, and social acceptance).

3.1.1. Biomass Resources

From the analysis, it became clear that implementing bioeconomy strategies at a regional level brought a series of challenges and opportunities in relation to the amount of biomass resources available

for industrial use (i.e., adding uses to the current food, feed, fiber, and energy). Additional challenges relate to the sustainable and effective use of land used to produce such biomass. Major changes are expected due to the proposed hierarchical use of the different biomasses, coupled with the available technology options and the potential for integrating supply chains [23,25]. Furthermore, as the demand for bio-based products increases, and more efficient technology options become more viable, the competition to utilize the biomass resources available will become more fierce [26,27]. However, this could also present new opportunities relating to encouraging greater collaborations between different regional stakeholders. Nonetheless, for this reason, the need to develop feedstock strategies at a national level was identified in order to: (1) Cope with such increasing resource demand and (2) lead to the harmonized use of biomass across the different producing regions within a country. Ultimately, these national feedstock strategies should be developed using bottom-up approaches, i.e., through complementing and integrating feedstock strategies unique to each regional context. In this way, the effective and efficient use of biomass resources is ensured, and the most appropriate technologies for supporting a sustainable regional bio-based industry are determined [28,29]. Ideally, the result of these strategies, promoting a greater integration and cycling of biomass, should also lead to a reduced pressure on the limited land available for biomass production.

Such an integrated and multi-level approach can help obtain a clearer understanding of the potential impacts caused by the increased use of biomass resources and at what scale these impacts might be occurring. Environmental, social, and economic impacts not only occur directly within the producing region, but can also be induced elsewhere, outside of these bioeconomy regions, due to the production activities of the various bioeconomy clusters and networks [26,30–33]. This leads to a quandary of scale when making impact assessments of bio-based systems, i.e., at which scale should assessments be carried out [34]. Therefore, it was proposed that, in order to make more robust assessments of circular and bio-based production systems, it would be necessary to derive an appropriate set of indicators that allows for their monitoring and evaluation in a regional context [35,36]. Such indicator sets should be able to evaluate not only the regional challenges and opportunities for implementing a sustainable bioeconomy, but also the associated global challenges (e.g., the UN Sustainable Development Goals (SDGs)) [15,37].

Overall, it was clear from the analysis that competition for various regional biomass resources would be a major driver for novel effective and efficient technologies to sufficiently meet market demand for sustainably produced bio-based products. However, to get to this point, there is a need to develop an effective biomass resource strategy, not only for the reasons outlined above, but also to support a better allocation of the available financial resources (i.e., research and development (R&D) funding resources) at the early stages of technological development [38]. Hence, to establish a regional bioeconomy, with a sufficient biomass resource base, the regional feedstock strategy should also take into consideration and/or be developed in parallel with the industrial development roadmap at regional and national levels.

3.1.2. Integrated Technology Systems (Collaborators)

There is a large and diverse range of individual technologies that currently comprise the “conversion system” associated with the bioeconomy. Therefore, in order to assess the status quo and the potential future challenges and opportunities relating to technologies, we have summarized the major technical developments, according to the four different types of biorefineries. These are currently in development at a European level and are defined as follows [39,40]:

- Starch/sugar biorefineries: Conventional biorefinery concepts based on starch and sugar crops and wood. Characteristic products include sugar, starch, oil, fibers, pulp, and paper;
- Oleochemical biorefineries: Based on oil crops. Main products include oils, glycerin, cattle feed, and biofuels;
- Lignocellulosic biorefineries: Based on lignocellulosic-rich biomass, such as straw, chaff, and wood. Characteristic (intermediary) base products include cellulose, hemicellulose, and lignin;

- Green biorefineries: Based on wet biomass in the form of green crops and leaves (e.g., pasture grasses, and sugar beet leaves). Main (intermediary) products include fibers, proteins, amino acids, and lactic acids.

Figure 2 shows the status quo of the technical development currently taking place in these four main biorefinery types. Moreover, it summarizes the following steps: Trends, future needs, and/or the next challenges that are envisaged in these four development areas.

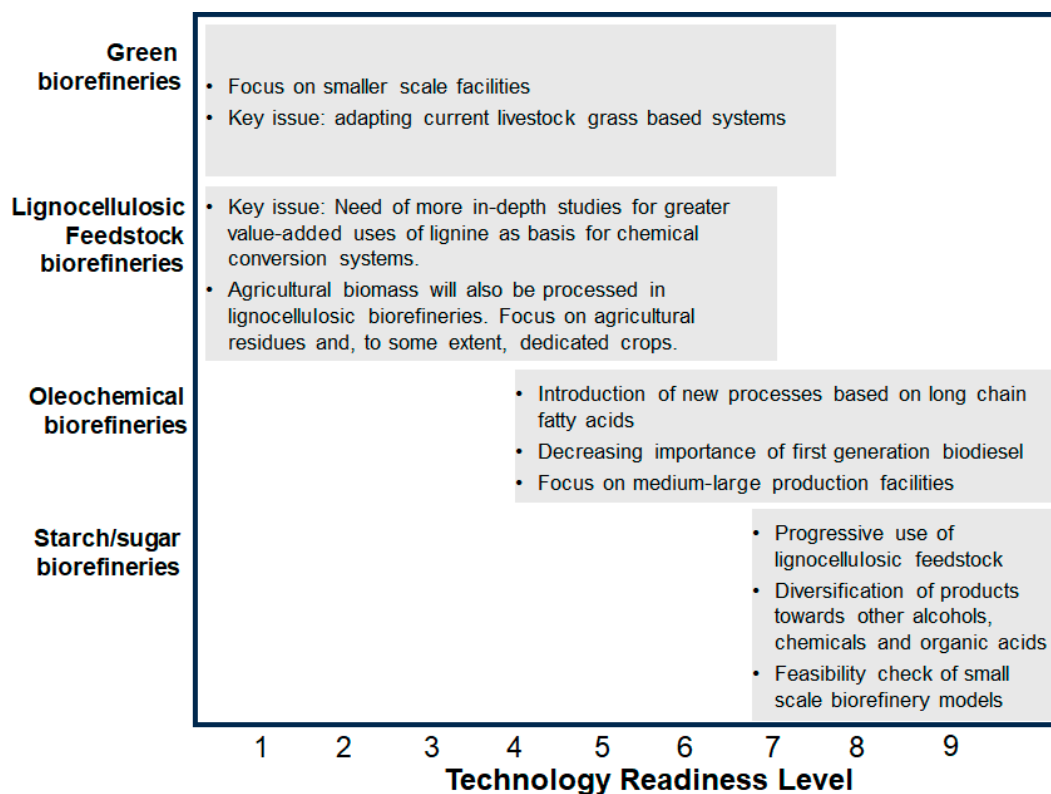


Figure 2. Overview of the status quo of different biorefinery types in Europe: The width of the boxes denotes the range of the technical development degree of the main technologies associated with each biorefinery type in terms of their TRL. Moreover, a summary is given regarding the next steps for fostering their technological development (adapted from [39–41]).

Figure 2 illustrates that besides the technologies associated with conventional biorefineries, based on sugar and starch, most technologies associated with the major biorefinery types are actually lying in the start to middle of their development potential. Hence, they are either currently or will be in need of support to jump over the “technological valley of the death” (Figure 1). It is therefore imperative to establish the necessary policies and measures that could allow for the further development of the most promising biorefinery technologies. Such measures could be decided as part of the regional development roadmap.

From the analysis, it can be seen that one way of facilitating the acceleration and implementation of the developed technologies in a region’s industrial sector is through the use of supply chain clusters and networks, which would include all the interest groups, as presented in Figure 1. Indeed, the European Commission outlined its desire to have a systemic perspective for the regional deployment of bioeconomies in order to enhance innovation at a regional level. They recognized that there is a need for linkages between different scientific disciplines, technology fields, and various other sectors in order to implement value chains into regional value cycles as a sustainable management of regional resources. For this reason, they outline the necessity to collaborate not only within one sector but also between clusters, sectors, and technologies so as to foster the bioeconomy on regional levels, as well as

outline the models of regional bioeconomic ecosystems as an integration of all relevant agents [42]. These clusters and networks could then be used as exchange platforms for discussion and knowledge exchange, as well as supply chain improvements, adaptations, and integration [43,44]. The use of these platforms is particularly important at the regional level (bottom-up), as they can help to identify key regional (and national) players, as well as encourage transparency and trust within and beyond the networks. This could be important for fostering a strong relationship between bio-based industries and society [45–50].

Unfortunately, the establishment of such collaborative networks is currently not the benchmark for the strategic development of suitable biomass conversion technologies. However, an increasing number of examples demonstrate that transparent collaborations among local partners, such as industrial representatives, regional and local authorities, as well as academics allows for faster identification of suitable technologies, regional strategic needs (e.g., employment, the use of surplus biomass, and infrastructure), as well as the steps and tasks necessary to establish a bioeconomy region [51–53]. Only by establishing these bioeconomy clusters and networks, as exchange platforms, will it be possible to establish the critical regional mass (e.g., the right actors and finance) that can determine the key technological developments needed to catalyze the sectoral integrations envisaged in the bioeconomy strategies. One of the first tasks of such regional collaborative networks would be to assess the nexus between regional biomass resources (inclusive of land limitations) and technologies, as well as supporting infrastructures. The results of this task could be used, together with the regional development plans envisaged by the local authorities, to produce a successful regional strategy for implementing the bioeconomy [54–58]. The next task would be a thorough evaluation of the potential impacts arising from the integration of the industrial and manufacturing sectors [12,43,59]. This will be key to determining the effectiveness of the proposed measures and actions, as outlined in the bioeconomy strategy.

3.1.3. Bio-based Markets and Social Acceptance (Neighbors)

There are certainly differences in implementing bioeconomy strategies, depending on the scale (e.g., national or regional), as well as how the bioeconomy is defined and the different focuses in developing bio-based products and markets. For example, in the Netherlands the focus is on developing bio-based building materials and chemicals. However, in Italy (Veneto) the focus has been on biomass for energy and biorefining from wood biomass. Additionally, there are macro-regional bioeconomy policies, for example in Eastern Africa, Latin America, and the Caribbean, as well as in various European regions. There are also national bioeconomy strategies developed in Argentina, Canada, Australia, and in many European Union member states. Many of the national bioeconomy strategies aim to respect the opportunities, challenges, and particularities of rural areas with a significant primary production sector. Their aim is to support collaboration between regions that show similarities in terms of resource availability and economic power. In this way, joint initiatives are intensified, the value of local resources is increased, job opportunities are created, and the regional innovation system, as a base for sustainability, is improved [60]. On a regional level (the scale below the national level), bioeconomy strategies are usually first intended to support economic development and create new forms of economic activities and markets. At this level, the stakeholders involved in implementing the bioeconomy are the regional government, businesses, and universities. However, to date, regardless of the focus or scale of the bioeconomy strategy, public engagement with local communities has often been limited [61].

In this regard, the majority of bioeconomy strategies emphasize the importance of a whole systems perspective and the involvement of the public in order to reduce societal consumption levels and achieve a transition to a sustainable bioeconomy. Various strategies consider the need to transform the societal mind-set and help modify behavior in a more sustainable direction. Therefore, one important goal of developing bio-based markets and bioeconomies at a regional scale is to understand the relationship between communities and the associated technological developments proposed

for integrated bioeconomy clusters [62–64]. This is particularly important in the case of bio-based technologies and bio-based products, as there is currently no real systematic assessment of what these relationships could or should be on a regional basis [65–68]. There is also a general lack of knowledge on the potential challenges for the societal acceptance of such bio-based products and their mainstreaming into the current and future marketplace [56,69–71]. While some sporadic traditional market assessments have been carried out by individual companies for their own particular products, the bioeconomic concept of integrated systems with co-products and shared products will require market analysis, along with greater collaboration and cooperation between key players, so as to take it from the concept to the marketplace. This will be a challenge, which will require understanding and knowledge of the complexities associated with introducing bio-based technologies and bio-based products into the marketplace. However, such an analysis could help to implement innovative business models that exploit both economic benefits, as well as techno-environmental and social advantages [72–76].

Furthermore, from the analysis, it was found that there is an increasing call for the development of socio-economic assessment and monitoring tools for assessing the potential impacts of bio-based technologies, industries, and their produced goods and services on a regional scale, and these should be given a high priority in the short term [77–80]. In this way, the potential impacts of technical developments on regional communities and society as a whole can be better assessed and thus provide a better understanding of how well the regional bioeconomy is performing. It will also help to make such products more transparent, and if carried out accurately and fairly, such assessments should help to dispel any criticism of a product “green washing” and thus help to secure a greater social acceptance of such production systems [81].

Another important aspect of the effective implementation of the bioeconomy strategy is to understand the actual influence of changing societal preferences and, hence, the markets for bio-based technologies and bio-based products [82–84]. Of particular interest are the questions of how and why social acceptance has changed. This will be a relevant factor for the success or failure of a regional bioeconomy and, in particular, for mainstreaming innovations in the biotechnology field [76,85–87]. A major driver for boosting social acceptance will be the measures that help raise awareness of regional communities regarding the potential implications of the bioeconomy at different scales, i.e., the local, regional, and national scales [88–90]. The inclusion of NGOs and organizations operating within local communities in the development processes of bioeconomy strategies will foster active citizen participation, which will help in defining the needs and challenges of society when implementing the envisaged regional bioeconomy strategy [91–97]. In this regard, the establishment of clear regional development goals that rely on the technical and human capacities found in a region, as well as a transparent information flow between the industrial sector and society, are cornerstones for overcoming the hurdle of public acceptance, encouraging the development of new markets for bio-based products [98–103].

Finally, the European Bioeconomy Stakeholders Panel pointed out that increased public awareness and improved communication are required. This includes the traceability and transparency of supply chains and the implementation of product certifications or labels on bio-based products in order to foster sustainable consumption patterns. They also outlined the challenges associated with the bioeconomy in the context of biomass availability. The mobilization differs according to the regional context, the biomass source, the cultural and demographic barriers, as well as the sparsity of secondary biomass resources, which all pose a challenge [104].

3.2. Results of the Multidisciplinary Workshop

3.2.1. The Nexus between Technology and Biomass Resources

It is important to rethink the technology development process. One must no longer consider only optimizing individual unit operations and/or industrial facilities, but should also consider the overall system, including all production facilities involved in a supply chain or network.

Economies of scale will still be a determinant for designing biorefineries and implementing large facilities that are still the preferred alternative for the reduction of the associated operative costs. However, future designs will increasingly consider the integrated regional networks, optimizing the use of local resources beyond the mere economic point of view. It was considered that while the processing of local biomass will be carried out on-site in decentralized facilities, the resulting intermediary products will be supplied to the regional industrial (centralized) facilities and sectors.

Moreover, the available regional infrastructure will have an increasing importance in designing bioeconomy networks. This will not only allow for the implementation of technologies in areas with established communication and service infrastructures, but it will also avoid using greenfields and thus reduce the stress on land resources.

Finally, it is imperative to develop evaluation and monitoring tools that can help in the implementation of bioeconomic systems, particularly at the regional level. Such tools should assess the value-added of technological alternatives to regional development and help optimize the supply chains in which these technologies are embedded, including the parameters from concepts, such as design for recycling, life cycle thinking, and circular resources management.

3.2.2. The Quandary of Scales

There is no straightforward answer to the scale quandary or whether a region is an appropriate scale to capture the impacts (environmental, social, and economic) of potentially emerging bio-based systems and their associated networks of technologies and biomass in and across landscapes. There is also not one simple answer to the question of whether piecing together individual parts of the puzzle (i.e., individual technological and environmental assessments) to produce a holistic picture would result in losing the overall systematic view (i.e., the total is not the sum of all parts). These, in turn, generate an additional question relating to the level of detail that should be included: Is it better to focus on the major aspects (i.e., a modelling approach), or should the assessment be closer to reality (i.e., detailed assessments, such as environmental impact assessments (EIA)). However, what is clear is that if the assessment focuses only on the major aspects (i.e., key activities, impacts, and metadata), the limitations and uncertainties should be made transparent in order to communicate effectively that there are “known unknowns”.

Additionally, the issue of social acceptance for bio-based products and the scale of assessment will become ever more pressing in the future. To date, the best means of communicating sustainability information to consumers is through labelling. However, many of these labels lack transparency in their calculation approaches. They can also be misleading, for example, organic labels are limited only to cultivation and neglect to include relevant upstream emissions during transport. Many of the labels only focus on one dimension of sustainability, with many disregarding the social conditions of production. Therefore, research is needed to design labels that cover more sustainable aspects on the whole biomass supply chain or that are more transparent by outlining the trade-offs. Furthermore, research is needed to understand how much detail should be included when assessing different impacts (i.e., social and environmental) and which assessment scale would help consumers to understand the overall picture.

While answering questions associated with the quandary of scale remains difficult to answer, one way to begin to start tackling it is the provision of two aspects associated with an impact assessment (environmental, social, and economic) being clearly defined and stated. These are: (1) The goal of the particular assessment and (2) the definition of scale. Through goal clarification, the particular context of the assessment can be outlined, helping to identify the strengths and weakness of the approach. The scale needs to be clarified, as there is currently no harmonized version of what is meant by a region, and this is something that needs consensus among the various scientific disciplines. However, context is key, and by establishing harmonized scale definitions and conducting studies on different bio-based technology networks at different scales, a knowledge base can be developed. In this way,

the best manner of assessment for different bio-based systems at different scales, depending on the goal of the assessment, can be identified.

3.2.3. Land Use Assessment—A Cornerstone for Evaluating the Bioeconomy

Land use modelling has been identified as an important dimension for enhancing knowledge about complex system interactions. This will be particularly important for the complex bio-based systems proposed for a bioeconomy. In particular, the question of what role technologies will play in the regional landscape and how the various aspects can be brought together to provide a comprehensive picture of the complexity of land use will need to be discussed.

Adequate modelling techniques will need to address issues relating to land use patterns and their local effects (e.g., emissions into soil and water) and regional effects (e.g., stability behavior due to the composition of various land areas, i.e., mosaics). Different models and modelling approaches are currently used to analyze land use. For example, forest dynamic models, coupled with ground water models to analyze fragmentation, as well as agent-based modelling approaches to analyze market and policy incentives. Furthermore, many ongoing efforts have been made to analyze socio-economic and environmental impacts via extended life cycle assessments. Coupling these material flow models with land use models is a promising way to bring the regional and spatial impacts to light. One example of this type of modelling is RELCA (Regional Life Cycle inventory Assessment), which couples technologies in the regional landscape with the relevant available biomass and hence provides a means of estimating regional land use and the environmental burdens associated with alternative bio-based systems [105,106]. Additionally, at an international level, the combination of material flows and land use will be particularly important for capturing the “spill-over effect” due to trans-national trade and use, as the increase of biomass use may result in undesired impacts elsewhere. One option for analyzing such effects could be the use of multi-regional input–output models, and indeed, such hybrid modelling approaches (i.e., models working in combination or integrated) should be considered in tackling the complex system issues arising from establishing bioeconomies, but these require further research.

What is clear is that a combination of approaches is necessary to include the intersection between bio-based technologies and land use, along with their associated impacts within the realm of the bioeconomy system. Firstly, a systemic view is necessary to handle the complexity. Secondly, material flows are the key means for analyzing environmental and socio-economic impacts. Moreover, spatially resolved material and environmental flows are a fundamental requirement for future assessments and the understanding of these complex systems. Finally, the coupling of material flow models with spatial and regional modelling approaches is a promising way to address the complexity of biomass and land use.

4. Conclusions

The goal of this work was to identify the most relevant aspects that hinder the mainstream of bio-based technologies and bio-based products within the bioeconomy and, in particular, bioeconomy regions. This paper makes an important contribution to the scientific discussion on the bioeconomy, as it is the first to identify the pivotal questions and challenges involved in establishing bioeconomy regions and the associated technological innovations. In this way, this paper can be considered a starting point for further discussions in relation to how regions should define their bioeconomy strategies, roadmaps, and activities unique to their own regional context, while adhering to national and international bioeconomy strategies.

From the research presented in this paper, it is clear that technological development and innovation in bioeconomy regions will be driven by resource competition. It is therefore imperative to establish effective and clear feedstock strategies that promote sustainable biomass use and management. Such regional feedstock strategies should not only prevent exhaustive resources use and unfair competition within a region, but they should take into account the potential impacts (environmental, economic, and social) on things outside of the region due to bioeconomic activities within the region.

To begin with, it is imperative to carry out a discussion at the regional scale in order to determine the nexus between the regional biomass availability and which technologies are compatible with a certain region. In this way, how technologies should be fostered and implemented to catalyze regional development towards a sustainable bioeconomy can be determined. Furthermore, based on the results, we propose a shift from the traditional technological development strategy, towards a more innovation-oriented technological development. The traditional technological development strategy becomes obsolete as a driver for innovation, as it lacks the “pull effect” (i.e., a technological development that meets the needs of the market and/or the manufacturing sectors), which is needed to actually overcome the hurdle of the valley of the technological death. This is referred to as “economies of scope”, moving away from the conventional concept of “economies of scale”, with one large scale industry dominating a region. By promoting the concept of “economies of scope”, bioeconomy regions will have a multitude of bio-based industries working together within networks and clusters, thus making it possible to set the desired diversified product basket based on a regional smart specification strategy. Thus, a region of collaborators is promoted.

Another task that needs to be carried out to foster an effective regional bioeconomy strategy is the involvement of local communities in its development. Public involvement in decision-making will help to enhance the social acceptance of the development of these new bio-based systems and technologies in certain neighborhoods. It will help to preempt the negative neighborhood symptom of “NIMBY” (not in my back yard). An additional benefit may also be that it helps to reduce societal consumption levels and achieve a transition to a sustainable bioeconomy.

While developing and implementing regional bioeconomy strategies will in itself be a major challenge, an additional challenge will be on how to monitor and assess the success of these emerging bio-based systems across various different regions. One major aspect to consider in the short term is the definition and understanding of the parameters affecting technological implementation within such bio-based systems, as well as the potential effects that these technologies may have on regional, national, and international levels. Furthermore, there is a greater push for developing socio-economic assessments and land use modelling approaches, which will aid in the understanding of the true sustainability of the deployment of bio-based technologies at the regional scale. Such understanding will be crucial for defining appropriate monitoring systems to assess the sustainability of the bioeconomy system.

According to this analysis of the implementation of the bioeconomy strategy, from a regional perspective, three major challenges (or a three-pronged challenge) were identified for innovative technological development:

- First prong—Resources: There is a need to establish a sustainable regional feedstock basis, as part of an effective regional feedstock strategy. This needs to take into account the current and future regional development of the bio-based industrial sector, as well as the overall national development goals;
- Second prong—Collaborators: It is important to foster supply chain clusters and networks, as these will provide exchange platforms that can deliver the necessary regional critical mass (in terms of both human capacities and the available infrastructure). In this way, technological innovation can be accelerated, and bio-based products can be mainstreamed;
- Third prong—Neighbors: There is a need to expand the current social systems analysis in order to capture important societal aspects at the regional scale. This will aid in the overcoming of the hurdle of social acceptance of bio-technologies and their representative bio-based products. Additionally, there is also a need for transparency between the industrial sector and society.

Tackling these three challenges should help to identify suitable technologies for the particular regional contexts during the early stage of development. Thus, it will be possible to mainstream the necessary resources to support the further development of these technologies and innovations,

thus helping them to advance to their next development stage and bridge the “valley of the technological death”.

Author Contributions: A.B., S.O.K., C.I., and D.T. prepared and carried out the workshop and analyzed its results. A.B. conducted the data curation and general analysis, as well as the conceptualization, writing, management, and submission of this research article. The manuscript has been edited and reviewed by all authors.

Funding: This work has been financed by the German Federal Ministry of Education and Research (BMBF) through the project “Leading Edge Cluster Bioeconomy” (FZK 031A078A), as well as by the Helmholtz Association of German Research Centers through the Program “Energy System 2050—A Contribution of the Research Field Energy”.

Acknowledgments: The authors thank the support of the partners of the project “Leading Edge Cluster Bioeconomy” (BMBF FZK 031A078A), and of the following Programs and Joint Initiatives of the Helmholtz Association of German Research Centers: “Sustainable Bioeconomy Portfolio”, “Cross-Programme Initiative ‘Sustainable Bioeconomy’”, “Technology, Innovation and Society”, and “Energy System 2050—A Contribution of the Research Field Energy”.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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